ZERO ERROR MARGIN

Airshow Display Flying Analysed

Des Barker

DEDICATION

This book is dedicated to the memory of all display aircrew and spectators that have lost their lives in pursuit of their passion for display flying and airshows. Deepest sympathies to all affected, the pilot's and spectator's families, their co-workers and friends, the public and the show organizers. There but for the Grace of God, go many display pilots.

FOREWORD

Chief of the South African Air Force,

The key to understanding the focus of this book is the acceptance of a singular reality; display flying, by virtue of the close proximity to the ground, poses a hazard to safety of flight.

I have been involved in display and demonstration flying, both as a member of the South African Air Force's *Silver Falcons* formation aerobatic team and enthusiastic spectator at many national and international airshows over the past thirty years. I have very strong feelings on the significance of display flying safety since the number of airshow and display flying accidents worldwide has seen a steady increase over the past ten years. Safety regulations have, in some countries been blatantly disregarded, particularly at the smaller airshows, yet still there is no international body or regulatory authority that exercises oversight for compliance with a universally accepted set of regulations and standards.

This book is thus intended to provide not only food for thought, but also some guidelines for consideration by those concerned with display flying in whatever capacity of involvement, whether as display pilot, aircrew, airshow organiser, display safety officer or 'anorak'. There is nothing new in this book; there is neither radical theories nor magic formulae that has been introduced to deal with the fallibility of the display pilot in the low-level display environment. In fact, the theory and techniques of aerobatics flying have been addressed at length over the years while books and PhD's have been written on human factors and human error.

But no book has addressed or attempted, for whatever reason, to address the airshow accidents, possibly for the possibility of casting a shadow on airshow safety. No common effort exists to capture airshow accident data to provide a basis for 'lessons learnt'. No attempt has been made to bring together the theory and dynamics of display flying with the real world experiences of airshow accidents. It is therefore hoped to encourage display pilots to bare their souls on their feelings, their experiences, their recommendations and last but not least, to speak up within their own airshow and display communities on their personal mistakes and 'close shaves'.

The book is designed to be a work on display flying, utilising a statistical analysis of randomly selected airshow accidents to highlight the traps involved while emphasising the hazards and the fact that there is zero error margin in the low-level display arena. This book has tried to capture the experiences of some of the most experienced display and flight test demonstration pilots in the world and presented as an overview of the techniques and key factors used by these specialist airshow performers in planning, practicing and flying their airshow routines. The shared experiences of specialists will hopefully stimulate thought in the field of display flying and thereby add to the safety and professionalism of airshows worldwide.

This book should assist airshow performers, operators and organizers alike to manage their way around some of the airshow anomalies while still providing the public with great aerial showmanship yet, without compromising safety. The information is pertinent and factual. It's written in the no nonsense style and highly experienced perspective that a book like this requires. It is specifically aimed at not being too technical with regular interspacing of information with the personal inside slant that should add to the value of the book as a teaching tool.

Professional flight display crews are composed of highly trained individuals who have no desire to make mistakes or errors of judgement. Yet mistakes do happen, even during the most carefully planned display sequences and such human mistakes can cause, and have caused, devastating accidents and also many "narrow escapes". There is no place for a non-professional pilot in this activity, the stakes are too high. In his "Fly Smart" video, Admiral Jack Ready (USN) summarises the essence of display flying: "When you begin flying the airshow for yourself, testing our own limits, showing off yourself and not concentrating on showing the airplane…you have stepped over the line into the realm of the non-professional air display pilot. The mark of the professional is the safe, well-placed, and smooth-flowing airshow performance".

Display flying is without doubt, a potentially a high-risk task for a pilot. All display pilots have an "Achilles Heel", a weak spot in their armour, which is generally not advertised amongst peers. The more we learn about ourselves and what others think about our displays and the more we exchange views on 'close shaves', the better will be our chances of combining survival with first rate demonstrations.

Lt Gen
CAF

Pretoria
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THE AUTHOR

Colonel Des Barker of the South African Air Force (SAAF), a fixed wing test pilot and previous Commanding Officer of the South African Air Force's Flight Test Centre (TFDC), is a member of Society of Experimental Test Pilots (SETP) and the Royal Aeronautical Society (RAeS). As an ex-member of the SAAF's national aerobatic team, the *Silver Falcons* and a demonstration/display pilot on several different types of fast jets including the Dassault Mirage F1 and the Mirage III (Cheetah - SAAF designation), he has thirty-three years of flying experience totalling approximately 6,500 flying hours on forty-five different military types, mostly fast-jets.

Published in the SAAF's aviation safety magazine *NYALA* , the Brazilian Air Force magazine *FORCA AEREA*, SETP's quarterly technical publication *COCKPIT*, the South African National Defence Force magazine *SALUT/South African Soldier*, *African Armed Forces Journal* and extensively in the South African general aviation magazine, *World Airnews,* market research indicated that there was no quintessential book on the subject of demonstration flying safety.

With this in mind it was decided that for such a work to have any credibility, an internationally collaborative effort would provide the optimal course of action. A group of reputable/credible and most importantly, highly experienced and enthusiastic aviation specialists, including Keith Hartley, BAE Eurofighter Typhoon test and demonstration pilot, Major Gregg Holden USAF C-17 display pilot, Mr Trevor Ralston Denel Aviation rotary wing test pilot, Kevin Mace ex-RAF Lightning display pilot, the Society of Experimental Test Pilots in the USA and several veterans of the international airshow world were rounded up to form a team and contribute to this book.

CONTENTS

PREFACE

The aim of this book is to address the dynamics of display and demonstration flying, in particular, highlighting the display pilot's physiological deficiencies and the factors affecting the safe presentation of a display/demonstration flight. Research has indicated that there is no book on the world market that addresses this subject from the perspective of the display pilot, in fact from any perspective, except photographic. There are several books on airshows; there are several books on the techniques and methodologies of flying the specific aerobatic manoeuvres, but none that look exclusively at the hazards imposed by low-level display flying at airshows or flight test product demonstrations.

No one has yet analysed the scope and magnitude of the challenges facing display flying in a world in which statistical evidence indicates an increase in airshow accidents worldwide as the popularity of airshows increases. Interventionist authorities have been established in certain countries with the sole purpose of regulating airshows to maximize spectator and display pilot safety. The disconcerting negative publicity attributable to each accident, the high costs of airshow security post September 11 and man's ever increasing demand for excitement and adrenalin, have placed huge financial and regulatory restrictions on one of the world's most popular spectator pastimes.

This book is an internationally collaborative effort written by highly experienced pilots for display and aspirant display pilots mainly, but non-display pilots, safety officers, airshow organisers and aviation enthusiasts would certainly find it interesting reading and learning from the real world examples and 'case studies'. The 'golden thread' remains safety of flight within the display-flying world. This is not an instructional textbook as such, it is not a mathematical exposition of safety of flight factors or aerodynamics, but rather a non-technical 'look' at the real world of display flying in all its various facets. The subjects addressed should stimulate thought and discussion on display and demonstration flying safety and if nothing else, should provide a display or aspirant display pilot with 'warning flags' to prevent accidents from repeating themselves.

Essentially, the question that is addressed is: "What is the scope and magnitude of the safety problems within the realm of airshow safety and how have such problems impacted on airshow safety". The problem is MAN, but unfortunately, there is no magic fix to solve the problems and overcome man's inherent physiological deficiencies. This book focuses on real world experiences with contributions by several different veteran display pilots who have survived the airshow circuit providing the lessons learned. It is not necessary to reinvent the wheel, others have gone before – learn from them.

By the very nature and high frequency and huge following of airshow events in the UK and USA, the book tends to address case studies mainly in these countries. However, since the attempt has been to make this an internationally collaborative work encompassing display flying all over the world, the authors and the contributors are a varied spectrum of pilots that have flown at the entire range of airshows from Farnborough International to local flying club 'Fly-Ins' and as such, the experiences and case studies from several other countries have also been included.

The book provides an overview of airshow safety but at a high level only without getting into lower level technical detail that could lose the interest of the enthusiastic reader. The book is historical, technical and system safety related, the writing style has tried to be free flowing, not textbook or flight manual style, written for pilots in 'pilotese' in many cases. It should provide easy reading but not be an instructional or aerodynamics manual even though the undercurrent is to teach and learn from other's mistakes.

The book covers background information for a display or aspirant display pilot whether military, civilian, professional aerobatic or flight test demonstration pilot to stimulate thoughts on improving display safety and personal survival. The focus is on maximizing showmanship without compromising, but rather improving safety by exposure to the mistakes previously made by those that have perished in pursuit of their display flying passion. The book brings together the theory and philosophies of display flying by connecting with the real world examples of airshow accidents and using the airshow accidents as a teaching tool in an effort to prevent such mistakes being repeated in the future.

The book offers thoughts on a number of issues, which directly and indirectly affect airshows, viz. the airshow as a business concern, the safety of airshow spectators and the general public alike and the impact of airshow crashes on society in general. MAN, as the weak link in the safety chain, is considered in terms of human error while airshow crash management, the role of the media, the anti-airshow lobby, regulatory authorities, the impact of increased insurance costs and the emotive issue of flying vintage aircraft at airshows is discussed.

The real world hazards of low-level display flying are presented not only through a brief review of 118 airshow accidents, but also by means of a statistical analysis which exposes the role of MAN as the weakest link in the safety chain and enables the integration of such accident data with the theoretical dynamics involved helping to bring theory and real world practices together. Given the risks at airshows, the basic causational errors of display flying accidents and the significance of airshow safety from the organiser's perspective enables definition of the airshow safety problem.

The scope of the book covers amongst other things, the Real World of Airshows including the business case, media, human fallibility, anti-airshow lobby, the case for flying vintage aircraft, etc. Accident case studies also provide the platform from which to study the display pilot's mind, decision making under high stress conditions and high pilot workload. In considering the display pilot, the pilot workload while flying the display is addressed and consideration is given to factors seducing the pilot psyche. Display pilot challenges are considered, questions are asked why highly experienced display pilots makes irrational decisions, how much continuation training and experience is required, while the question of age and the life of a professional aerobatic pilot are considered.

No appraisal of display safety would be complete without considering the specific dynamics and aerodynamics of low-level display flying. In particular the aspects of closing speed, pilot reaction times, the limitations of display volumes, energy management, pitot/statics, density altitude, ejection, manual bail-out and departures and spinning. A high level presentation of display flying dynamics and aerodynamics assists in placing in perspective the objectives of the display pilot in optimising performance and handling qualities for the display routine.

In considering display specifics, subjects addressed are the selection of display pilots, planning considerations for specific show routines, manoeuvres and routine selection. Philosophies regarding practice, simulator preparation and discipline are essential considerations in preparing a show routine and as such the flight envelope, carriage of passengers, fuel allowance and weather considerations are discussed. Flying the actual display is reviewed through the use of real world examples while the philosophies and 'rules of thumb' for flight test demonstration flights are covered in terms of the role of management, Buyer's team requirements, briefings and reporting.

Finally, an effort is made to put the reader 'into the cockpit' by exposing the emotions and particular physiological stressors facing the display pilots flying on 'show day'. The display pilot, the psyche of the pilot, effect of cockpit ergonomics, pilot workload, the safety dynamics/aerodynamics of display flying, airshow accident case studies, including the world's worst airshow accident, causal factors relating to safety, displaying vintage jet and piston warbirds, the routine planning, choreography, safety factors, demonstrating the different categories of aircraft from the C-17 through to the Eurofighter, flight test commercial demonstration flying, etc. and much more.

The primary aim of the book is to highlight the Man's contribution to airshow accidents (78%), weakness, challenges and exchange/pass on information and lessons learnt on the skills/art of demonstration flying in all its various contexts - hopefully stimulating a greater emphasis on safety of flight in the hazardous arena of low level aerobatics. The air show circuit is currently under threat following Sept 11, high insurance and security costs, high accident rates, etc.

In 2001, there were at least 15 air show accidents worldwide, in 2002 there were at least 14 - hopefully, there will be no more in 2003. Airshows are big business the world over and every accident adds to the negative perceptions of the world's second most popular spectator pastime. If this publication could add to improving an understanding of the human factors involved and safety of flight just 1%, it would be worth the effort.

The tenets expressed in this book are those of the author and contributors and do not necessarily represent any Company or Society.

AUTHOR'S ACKNOWLEDGEMENTS

his book should be carefully read by anyone interested in display flying and airshows, either as a display pilot, an aspirant display pilot, an ex-display pilot, display safety officer, airshow organiser or enthusiastic spectator. Compiling a book of this nature could not have been done exclusively without the sharing of real world experiences and contributions by display veterans, show organisers and display safety officers. As such, a debt of gratitude is owed to those that shared their vast experiences with the display and demonstration flying fraternity worldwide in an effort to promote display flying safety – after all, "safety is free".

The idea for this book was initially conceived by a team which included the author, Colonel Des Barker (SAAF), Mike Beachyhead (Thunder City, South Africa), Nigel Lamb (Breitling Collection, Duxford) and Wing Commander Andy Offer (ex – *Red Arrows* leader). The following contributors are acknowledged in chronological order for their direct contributions:

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CHAPTER 1

REALITIES OF THE AIRSHOW WORLD

Royal Air Force Red Arrows at the Salon de Provence AFB national airshow celebrating the 50th anniversary of the Patrouille de France, 18 May 2003. (Antoine Grondeau)

"Any pilot, given the task of providing a display for the public, should set out to thrill the ignorant, impress the knowledgeable, and frighten no one". (Squadron Leader Ian Dick, former leader of the Red Arrows)

THE AIRSHOW BUSINESS

Display flying has not only become big business worldwide, but as in any theatre production in London's West End or on New York's Broadway, it is also a major entertainment and spectator pastime. In the United Kingdom, particularly, it is interesting to note that airshows are rated as the second largest spectator sport after football and in the United States, such high-flying events are second only to Major League baseball as America's favourite family event, even ahead of NASCAR auto racing. It is also one of the most hazardous and each year, aerobatic pilots are killed while displaying their aircraft at airshows and commercial demonstrations.

From 'Barnstormers' to *Blue Angels*, antique aircraft to supersonic jets, each year there are an astonishing 300 to 350 airshows in America alone, entertaining over 24-million spectators. From futuristic festivals to billion-dollar expos, spectators are able to explore the world of amazing aerobatics and their ever-evolving aircraft and see how aviation technology has advanced airshows, and how airshows have advanced aviation. In the UK, a total of 165 airshows were held during 2001, down from the average of 250, mainly attributable to the foot and mouth epidemic that occurred in 2001.

The popularity of airshows is understandable because you don't have to pay £35 a seat or £3.00 for a bottle of water at an airshow, it's usually an affordable event and one gets to see some of the world's best pilots perform with grace and skill, sometimes with humour, and certainly with *panache*. Some of the pilots are wearing military medals, the kind that are only given to genuine heroes, others are simply civilian aviators who sacrifice their time, talent, and money, just to keep the dream of flight alive. Unfortunately, unlike some professional athletes and pop stars, most airshow pilots don't earn six figure incomes, even though they are a crucial entertainment component of the largest attendance events in the world - but they have something that few others ever have…extreme job satisfaction!

With 200 aircraft typically on static display at the Royal International Air Tattoo, the display line is approximately two miles long and the airshow is attended by in excess of 200,000 local and foreign visitors during the two public days. (RAF Benevolent Fund)

Hand in hand with spectator attendance naturally go revenue earnings, enabling the airshow world to sustain itself to a degree. It is certainly not a lucrative "money spinning" venture, but it is as a commercial sales platform, capable of generating multi-billion dollar contracts at the trade shows. The actual organising, presentation and participation in airshows also provides a livelihood for a small percentage of people worldwide, particularly professional display pilots and then of course, benevolent societies and their staff. Larger airshows such as Farnborough International and the Royal International Air Tattoo in the UK, permanently employ staff that plan each year's show a year in advance, down to the finest detail.

The first airshow ever is widely acknowledged to have been held at Reims, France as early as August 1909, where some of Europe's most famous aviators gathered to 'wow' the crowds with their new flying machines. The ability to just get airborne was in those early days an achievement on its own. Four years later in 1913, a Frenchman by the name of Pegoud was the first person to perform aerobatics in a specially strengthened Bleriot and in the same year, Piotr Nesterov made the first loop on 20 August 1913 in a Nieuport Monoplane. One of the first airshows in the United States was held at Los Angeles, California in January 1910, where Glenn Curtiss was among the participants. By 1912, the U.S. Navy had already staged the first of many simulated dogfights at airshows and since then, manoeuvre routines have progressed steadily. Today, military flight demonstrations and aerobatic teams such as the *Red Arrows, Thunderbirds* and *Blue Angels*, to name just a few, are a standard component of the air forces of many nations.

It was Mr Jean Coreau, Avions Marcel Dassault test and demonstration pilot that said: "Bringing together numbers of different aircraft of all types and categories from different nations on the same airfield and let them fly all day long in front of spectators, you are building one of the largest theatres in the world. If the fame of the show is big enough, it increases each year and you can reach millions of spectators."

Since the beginning of aviation, the stage has remained the same, but the increase in performance and choreography has been amazing. A series of very short flights, which hardly demonstrate even a fraction of the aircraft's potential, provide the spectator with hours of entertainment; many spectators secretly wishing to be the pilots actually 'putting the aircraft through its paces'. At the same time, the rules governing airshow flying have become increasingly restrictive in terms of airspeed, altitude and manoeuvres, but modern aircraft, through their increased performance and agility, are currently able to comply more readily with the ever-increasing arena restrictions. For the display pilot, the display arena is a highly charged, hostile environment that requires absolute professionalism and the demonstration of the highest levels of flying skills. There is no room for mistakes, poor discipline or poor judgement by the display pilot.

So, with the primary requirement of the display pilot being to entertain and demonstrate the air vehicle, what are the basic guidelines of a good display? Well, simply to remain in view of the spectator while demonstrating the performance and flying qualities of the aircraft in a relatively short space of time, anything from four to eight minutes, typically. Safety rules are imposed not only to restrict the manoeuvres due to available display volume, but also to reduce the risk to the spectators – such rules have evolved down the years, based on accidents and incidents of the earlier display pilots. In more modern times, such rules are obviously easier to comply with by helicopters, low speed and VSTOL aircraft, but for the high performance aircraft, the piloting skills level required has increased as has the requirement for aircraft manoeuvring potential and agility.

Since the ‘barnstorming’ days following the end of World War I, when ‘surplus to military requirement’ pilots and aircraft struggled to make a living in recessionary financial times, the airshow circuit has progressed steadily. Interestingly enough, the rate at which airshows have developed worldwide as a business and a spectator sport, has accelerated exponentially over the past fifteen years. Airshows have attracted many millions of dollars in sponsorship, not only for the aircraft, but also for benevolent societies, museums and airfields.

AIRSHOW CATEGORIES

There are essentially four different categories of airshows, the commercially orientated Business or Trade Shows, Military Shows, General Aviation Shows and Special Events such as “Fly-Ins”, carnivals, music concerts, tall ships and coastal resorts. Business shows, usually presented on a bi-annual basis such as Britain’s Farnborough International Airshow, France’s Paris Airshow (Le Bourget), the United State’s Dayton Airshow (also referred to as the United States Air and Trade Show) and Russia’s MAKS, serve as some of the major showgrounds for commercial sales in which the primary objective is the sale of aircraft and systems. Such huge commercial ventures are normally presented on behalf of governments and their Ministry’s of Trade and Industry, in cooperation with state aircraft, space and defence branches of industry that organize and present such international aviation and space salons.

Commercial airshows and exhibitions present the latest aerospace products and technology and have become a traditional and respectable site for negotiating business contracts of mutual interest. The huge market and unique potential of science and technology, attracts many specialists representing the world’s aircraft, aerospace and transport industry. Typically, at Russia’s MAKS exhibition, more than 400 aerospace companies and organizations from twenty-four countries take part in the exhibition while more than 150 aircraft participate in the air displays.

Aircraft of all types and their applications are on display. Vendors of rocket systems, spacecraft and satellite technologies, aircraft and rocket engine technologies, airborne and ground-support equipment, navigation and flight control systems, aircraft weapon systems, missiles, air defence systems, flight safety systems, materials and technologies, airfield equipment, electronic communication systems and computer technologies, all form part of the commercial exhibition showcasing their technologies.

During the large commercial airshow flying-programmes, some approximately 380 flights are typically flown. The attendance by the “who’s who” of the aerospace business makes it appropriate to concurrently host numerous symposiums and seminars which are also presented to promote the interchange of scientific and technological information. In terms of attendance over the 5 days, between 500,000 and 1,000,000 visitors could be expected to attend the major exhibitions such as Farnborough, Dayton and Paris.

Billed as the world’s premier aerospace event, the Farnborough International 2002 Airshow saw 1,260 companies exhibiting at the seventeen National Pavilions with fifteen different countries providing aircraft on display. The Society of British Aerospace Companies (SBAC) announced $9-billion worth of sales and contracts and 170,000 trade visitors attended the trade days preceding the public days.

The second category, Military Airshows, whether Navy, Army or Air Force, has as its main objective, recruitment of young men and women into the military. In contrast to the Business Trade Shows, the focus is a personnel recruiting and public relations effort, not necessarily always showmanship. As an example, the stated mission of the *Blue Angels* is “to enhance Navy and Marine Corps recruiting and to represent the naval service to the civilian community, its elected leadership and foreign nations”. The *Blue Angels* serve as role models and goodwill ambassadors for the U.S. Navy and Marine Corps, representing the best of naval aviation. A *Blue Angel* s flying display exhibits the choreographed refinements of Navy-trained flying skills, presenting aerobatic manoeuvres of the four-plane diamond, as well as the fast-paced, high performance manoeuvres of the two solo pilots.

Military airshows are organised by the military themselves and are essential components of any armed force’s public relations campaign to provide the citizens of that particular country with exposure to the aviation hardware available to that country. People want to see where their tax money is going and watching the ‘demos’ like those at the airshows, really shows them what they get for the billions that they pay in tax. Military airshows can, and have often been used as a ‘show of force’, particularly during the Cold War years.

In the USA, air support officials at the Horsham Air Station said the ‘Sounds of Freedom’ Airshow was designed to invite locals onto the base to see their tax dollars at work. The show had been held periodically since the Navy took over the base in 1943, and private performances were held even before that. In 1997, when the *Blue Angels* performed, the base drew nearly 500,000 spectators. Local and national military officials touted the events as an important recruitment tool, especially as overall enrolment in the armed forces dwindled. Milton R. Shils, president of the Delaware Valley Historic Aircraft Association, said that the ‘Sounds of Freedom’ Airshow was important to his group for publicity and recruitment, and the members anticipated the festivities each year.

However, more importantly, the World War II veteran said that the events inspired young adults not only to join the military, but also to become aviators. He pointed to his own past, as a teenager he had met Amelia Earhart and Charles Lindbergh at an airshow and was encouraged to become a pilot. “As a child, to reach out and touch these aviators was inspiring,” he said. “They can be ground mechanics, they can be crew chiefs, or aviators themselves - these are the men and women that help keep peace around the world.”

In the case of the Royal Air Force, the *Red Arrow’s* team was for many years a very potent recruiting agent, although that is less true today. A significant number of officers and airmen, not just aircrew, used to tell the Recruiting Staff that they wanted to join the RAF because they had enjoyed watching the *Red Arrows* atair displays. The *Red Arrows,* in turn, demonstrate British skill and technology to an enormous number of people each year, including over 2.5 million Americans during the 1993 USA Tour and several million more during the 1995/96 tours of the Middle East, Africa, Far East and Australia. At Sydney Harbour alone, 650,000 spectators watched on ‘Australia Day’ in January 1996. Since their establishment on 6 May 1965 until the end of the 2002 season, the *Red Arrows* had flown 3,654 public displays in 53 different countries. The fact that British Industry was prepared to fund similar tours to the Middle and Far East in 1997 and 1999 seems to confirm the positive return on investment for both the aerospace industry and the Royal Air Force.

The Royal International Air Tattoo (RIAT) in the UK, has as its aims not only the raising of funds for the RAF Benevolent Fund,

The 170,000 member EAA Convention at Oshkosh, normally held annually in July of each year, marked its 50th anniversary in 2002 and included one of the largest gatherings of active military aircraft ever at AirVenture.

but is also cleverly aimed at facilitating interaction and contact between air forces worldwide, making it a truly international military airshow. RIAT is in fact, a privately funded enterprise that pays its own way and celebrated its 31st anniversary in 2002. It is claimed to be the largest military airshow in the world with approximately thirty-five air forces providing 150 aircraft in an uninterrupted eight hour flying display. It is also the only airshow in the world in which air forces compete against each other over a three-day period for several trophies in different air and ground categories.

The third category is the General Aviation shows, the largest of which is, of course, the USA's Experimental Aircraft Association's (EAA) AirVenture held annually at Oskosh. In this case, the association uses the airshow to exhibit its latest experimental and home-built types, exchange information on aircraft, systems, flying techniques, education and social interaction. In spite of the apparent capitulation by the Experimental Aircraft Association's leadership to the Marketing gurus, EAA's annual AirVenture 2002 was still the 'primo aviation event' of that year. Nowhere else in the world was there such a blend of aircraft, flying, products, performances, projects and sheer entertainment to satisfy every aviator and enthusiast.

The modern trend is that most airshows tend to have a specific theme or set of themes supporting the airshow event and in 2001, the theme at AirVenture was 'Aviation Firsts'. Special attention was given to those who had participated in any number of firsts, first through the sound barrier, first to reach Mach 2, first to fly around the world un-refuelled, first around the world in a balloon, first African-American fighter group, first female space shuttle commander, to mention a few. Some 750,000 people visited and even though down from previous years, about 10,000 aircraft 'flew in', including over 2,400 show planes, 653 homebuilts, 135 amphibian/floatplanes/sea-planes, 103 antiques, 23 aerobatic, 434 classics, 389 ultralights, 316 contemporaries, 419 warbirds, 8 specials and 1 replica.

For six days, with over 500 educational forums, more than 750 exhibitors including exhibits by NASA and the USAF, combined with non-stop flying displays, made this one of the prestige aviation events in the world. Such top-quality airshows naturally not only attract hundreds of thousands of spectators, but also some of the world's top aerobatic pilots who provide the best demonstration flying that aviation has to offer.

In April 2002, the Sun 'n Fun in Lakeland, Fla., the second-largest aviation event in the world, attracted more than 630,000 people. There were 7,500 aircraft, 500 exhibitors and 3,000 volunteer staff. Also in 2002, the world famous Biggin Hill Air Fair in the UK celebrated its 39th anniversary while at Duxford, home of the Imperial War Museum's flying warbird collection, four major airshows were hosted; each year, approximately 500,000 spectators attend the airshows and visit the museum.

As the 50th anniversary AirVenture convention wound down on 28 July 2002, EAA president Tom Poberezny gave his traditional wrap up to the media. "I couldn't be happier," he told reporters. Final numbers weren't ready, he said, but a reasonable guess at attendance would be 750,000, short of a record, but still a healthy total. With the uncertainty in the economy and 9/11, they still came out in great numbers," he said. The number of exhibitors set a record, and vendors were happy: "This is all anecdotal but by all reports, they did very well and better than expected. It's very encouraging at a time when everyone is worried about the economy." As the number of aircraft parked at Wittman Field topped 2,500, new areas had to be opened up – participation and attendance on such a huge scale bears out the popularity of such aviation events in the USA.

Then there are, of course, the hundreds of smaller airshows all over the world – maybe not necessarily as well publicised and attended as the major international events, but the hazards and threats to safety of flight are nevertheless the same as at international airshows. In fact, the smaller airshows at remote airfields may even pose greater hazards and risks due to poor supervision and regulation enforcement, topography, mountains, high-tension wires, birds and lack of sophisticated fire and rescue services.

It bears mentioning that many civilian airfields are responsible for the maintenance, repair and overhead costs of their facilities, all at a cost to the members of on-site flying clubs, the local community or municipality. Many airfields even house museums and vintage aircraft collections. Maintaining such facilities is expensive and in many cases, such airfields present an airshow at least once a year to generate the funds necessary to subsidise their existence and activities.

There is no question about it, airshows are an accepted entertainment medium worldwide with evidence that it is growing steadily. The future growth rate will however, be determined by threats to safety and the increased costs induced by security.

Today more and more heavy and high performance aircraft are being operated on the airshow circuit. A few years ago, the thought of high-powered piston and ex-military jet aircraft being displayed by civilian pilots around the world, was unthinkable - today it is a reality. Civilian and ex-military pilots alike, can and do get their hands on high momentum, high-powered machines and this up's the ante in terms of potential airshow accidents and incidents. The need to perform and demonstrate is high and the desire for these pilots to show-off their proud acquisitions often leads to accidents as their inexperience battles to come to terms with high torque values, old vintage aerodynamics and high momentum. And then of course, there are a large number of aircraft operators all competing for a limited 'budget pie' which places pressure on the operators, not only in financial terms, but also in terms of the kind of aircraft and acts that they need to provide.

In some countries and particularly the UK and US where ex-military and some experimental airshow aircraft operate on a permit or exemption basis, meaning that they may not be operated for commercial reward, airshow revenue is often the only or major source of financing this venture. Inadequate funding can also lead to operators not applying the commensurate high levels of maintenance required, not getting sufficient display practice and perhaps pushing themselves to provide airshow organizers with a more spectacular 'act', particularly when two similar types are competing for the same slot.

A new entertainment phenomenon on the airshow circuit in the USA and gaining in popularity as an alternative format to airshows, is air racing. Air racing has moved on from being an independent racing event and has been integrated into the airshow format on certain occasions. The Formula V Air Racing Association is the pioneer in adapting air race operations to the established airshow format and its FAA-approved two-mile racecourse, fits most airshow sites. Each aircraft carries $1 million liability insurance coverage and all aircraft are single-seat, homebuilt experimental licensed, built especially for air racing, and powered by 60 hp engines. These racers reach top speeds around the racecourse of over 170 mph. Using a variety of colour schemes, raceplane design itself, is regulated by the association while technical and safety inspections are performed by the association before each event to ensure compliance with the rules.

Closed-course pylon air racing for Formula V is generally two or more daily air races around a two-mile oval course directly in front of the crowd. The race starts from a stationary start on the runway; the aircraft takeoff in rows, then turn onto the race course and fly eight laps. What appears especially exciting for the spectators is that racing altitude is 50 to 100 feet above ground level which makes for spectacular viewing, in fact, this air sport is regarded as a true competitive airshow sport with broad spectator appeal, similar to auto races. All race pilots hold FAA-recognized "Letters of Air Racing Competency" issued by the Formula V Air Racing Association. The popularity of these events is slowly increasing amongst airshow spectators looking for that extra excitement from airshows that regulations have over the years, somewhat dampened. By the very nature of airshow racing, it is equally hazardous and several spectacular accidents have occurred in the past few years.

DEFINITIONS AND TERMINOLOGY

Although no formal definitions appear to exist for the various categories of aviation exhibitions, based on the Longman Family Dictionary, the following definitions are considered appropriate in the context of airshows. The word "exhibition" is defined as "a public showing" and therefore makes all public aviation showings, be they a static or flying, an exhibition of some sort.

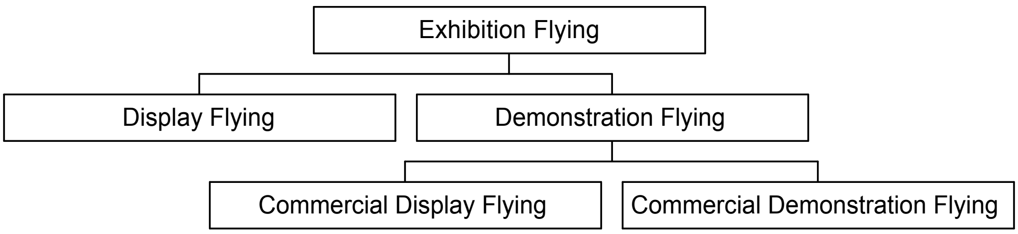
In terms of aviation exhibitions, further subdivisions are possible, the word "demonstration", as a noun is defined as "a showing and explanation of the merits of a product to a prospective buyer" which immediately brings with it the connotation of a commercial venture, thus the terminology 'commercial demonstration'. The word "display" as a verb, means "to expose to view", and as a noun "a presentation or exhibition of something in the public view".

Exhibition flying may thus be subdivided into two sub-sections, 'display flying' typically associated with that seen at airshows worldwide and 'demonstration flying', such as commercial demonstrations to prospective customers. The demonstration flights can be further subdivided into 'commercial display flying' and 'commercial demonstration flying', dependent on the ultimate objectives of the flights.

In the case of the 'commercial display flight', the pilot displays the all-round performance and flying characteristics to the prospective buyer's team watching from the ground. The 'commercial demonstration' flight on the other hand, typically includes the carriage of the prospective buyer's test pilots, representatives or technical members of the evaluation team; the technical assessment and details of the aircraft are relevant in assessing the performance and handling qualities of the aircraft. The 'commercial' display or demonstration flights are also referred to as 'product demonstration flights'.

SPECTATORS

So, who normally attends airshows? Why do they go in their thousands, often spending several hours to reach their destinations? What is it that makes spectators continuously return to specific airshows year after year? Although accurate information is not readily available, statistics gathered by the International Council of Airshows (ICAS) in the United States through their Event Organizer Survey during 2000, estimated that between 15 and 18 million spectators attend between 300 and 350 airshows throughout North America each year. Figures released by ICAS



Schematic Diagram of Exhibition Flying Definitions.

also indicated that airshows draw large numbers of demographically attractive spectators - a well-educated, affluent group of men, women and children of all ages; 36% are female, 64% male, 41% are single, 59% married. In 2000, more than 70% of the audience at an airshow had some college education and 75% reported a household income of $35,000 or more. Interestingly enough, the average spectator was just under 39 years of age, but more than 53% of spectators were between 30 and 50, indicating that airshows cater for a wide spectrum of spectators, both the young, future aviation recruits and also the more mature, 'old hand'.

Two years later, the 2002 Airshow Spectator Survey conducted at 20 different locations, surveyed 4,000 people at airshows in North America with questions ranging from how far they drove to see the show, to how many people think they're getting a good enough 'bang for their airshow bucks'. The ICAS survey revealed that the average spectator was 41 years old with an average household income of around $55,000 annually. Most had some college education, although not necessarily a degree and drove less than twenty miles to bring the family to see the show at which they will spend between three-and-a-half and five-hours at the event and more than likely, they have been there before. "Indirectly, the spectators are telling you that they're going to be back at your show next year," said International Council of Airshows President John Cudahy. "So it would be worth your while to reach out to them, make them feel like part of something." Particularly interesting statistics are that only 10 to 15 % of the airshow audience are real 'aviation enthusiasts', the loyal fan base if you will, so 85 % of the crowd choose to go to an airshow for 'a day out'! For these people aviation and flying is today taken for granted and it is this group which need to be focussed on to ensure large attendance at future airshows.

The biggest draw card? In the USA, military aerobatic teams like the *Blue Angels*, *Thunderbirds* and Canada's venerable *Snowbirds*. "Is that any different than before 9/11?" asked

Cudahy? "No, so that suggests to ICAS that we need to continue to support the military however we can." After military demonstration teams, spectators said they came to see modern military aircraft, military static displays, civilian flying exhibitions and warbird static displays, in that order. Although the poll is conducted every two years, Cudahy said he wanted to get behind the numbers. "We want to know more about 'psycho-graphics' as opposed to demographics. What do spectators do for a living? How many times have they gone skydiving? What kind of car do they own?" The ICAS president said that the organization would begin taking samples on lifestyles and spending patterns again from 2003. While home ownership and household income rose between the 2000 and 2002 surveys, education and male-to-female ratios were roughly the same. What to do with all these numbers? Cudahy said he had a plan. "We're working to contact national-level sponsors and brand managers, to tell them there's a fairly sophisticated audience at airshows", he said.

On entrance charges, Cudahy said "My personal feeling is that prices are too low; the average price for an adult ticket in 2000 was $8.00 and while most military shows, indeed the three biggest shows in North America are free", the survey showed most people would be willing to pay more. A variety of factors obviously affects attendance figures at airshows in a given year. For instance, does the airshow charge admission or is it free? Is weather a factor, or have there been scheduling concerns? Traffic congestion is one of the major aspects that adversely affects the spectators enthusiasm; airfields were not designed to handle the almost instantaneous dumping of between 120,000 to 200,000 spectators on their doorsteps. Fair comment from a disappointed enthusiast: "Almost 70,000 spectators at the last 'all team' *Snowbirds* , *Red Arrows* , *Thunderbirds* publicity gala and just getting there was a half-day experience. This from a guy who was up at 4 a.m. to try and get the 'morning experience' with just the pilots and aircraft on the flight line at 6 a.m. –7 a.m., and for what?"

RIAT 2002, returning to RAF Fairford after two years at RAF Cottesmore following major upgrading to Fairford, provided the British enthusiasts with a glimpse into the future format of airshow logistics following September 11. Personal body searches to each of the 100,000+ spectators and poor vehicle access to parking areas, resulted in a fifteen-mile long traffic tailbacks which took vehicles up to four-hours to traverse. Many irate spectators turned away and vowed never to return but rather to use their savings to make the trip to Oskosh instead. Yet, despite the 'bad traffic days', there are a number of airshows worldwide whose attendance figures continue to place them among the highest attended shows in the world.

It would appear that 'Bad traffic days' are a common problem for airshow spectators worldwide. According to a report in the *Greenville News* (USA), airshows aren't dead, despite the best efforts of the uninformed press, the FBI, the TSA, and befuddled local officials. The 2003 Greenville (SC) Air Festival held in April, which featured the Air Force *Thunderbirds* and the *Green Beret* jump team, flooded the Donaldson Center. The resulting throngs created "a massive traffic jam that snarled cars and trucks and forced some people to park wherever they could and walk miles to the airshow's location."

Some of the show's 60,000 estimated ticket-buyers wanted their $20 back, saying the show's planners didn't do their jobs, the police traffic detail was too small and the volunteers weren't trained. The paper noted that "Chuck Hodge, executive director of Greenville Events, said about 40,000 watched the show from inside the Donaldson Center on the Saturday afternoon while another 15,000 watched from outside. "We honestly just got overwhelmed," he said. People parked everywhere. Some 5,000 cars made it into the real parking lot; others stopped by the roadside.

What was the problem? When something's this screwed up, in most cases, one has to look for bureaucratic involvement. Sure enough, in this case, the paper noted, "Part of the problem was that organizers had to switch where ticket holders entered at 1 p.m. The main entrance was on Delaware Street but organizers had to reroute drivers to a narrower road to comply with Federal Aviation Administration regulations on where an airshow audience could sit." What is evident from the two preceding examples, is that in modern society, man's patience has become shorter, the ability to sustain the frustration of long queues at any event is one of the major challenges.

The modern fare-paying spectator does not want to 'struggle' to be entertained, after all, they are paying for entertainment, not frustration. Surely, the most important advise to airshow organisers therefore, is to ensure that the fare paying spectator's entertainment pleasure is not frustrated by poor logistics, that the basic essentials are in place. Under basic essentials, the first element is access, access to the venue must be relatively easy without long hours spent trying to gain entry; this implies that traffic flow should be relatively unimpeded and that security checks should not result in a build-up of thousands. Sufficient spectator enclosures must be provided with easy access to food and beverage outlets while toilet facilities must be readily accessible. Failure by show organisers to meet the minimum requirement of the spectator's basic needs at anairshow, will negate the opportunity of getting the spectators to return next time around.

Although spectators worldwide are required to pay entry fees at most airshows, there are cases at military airshows in most countries where no entrance fee is charged. This is due mainly to the fact that since the aircraft and airshow resources are funded by taxpayer's money, the principle of charging a fee for the taxpayer to see 'his own equipment' demonstrated, is difficult to justify. However, in recent times, this 'honourable' principle has been overridden by the stark realities of shrinking military budgets worldwide, air forces having to use the entry fees to subsidise the overhead costs of presenting the airshows.

There is no stereotype airshow spectator; airshow spectators, just as theatre or moviegoers, extend across the entire range of the personality spectrum and they are selective in their choice of airshow attendance, wanting to see some specific aircraft types or a specific pilot displaying a particular aircraft. Rumours, media speculation or reported unserviceabilities are often sufficient to make the more 'selective spectator' hesitant to attend.

Not only is there also a difference in preference between fixed wing and rotary wing enthusiasts, but also within the fixed wing category, there are significant differences in spectator preferences. Asked what spectators 'liked the most at airshows' in the USA, the reactions varied from person to person – the answers provide an educational insight into the mind of some of the airshow spectators. "If showmanship was the criterion, I'd vote for the F-16 displays which are ten times more exciting than a bunch of aerobatics. I tend to find prop stuff very boring, I like the whole spectacle of a jet display - the noise, the afterburner flame, the car alarms going off", was one opinion.

On the other side of the opinion spectrum: "aerobatics is about as exciting in jets as watching a dog sleep - the kind of aerobatics I like to watch have to do with amateurs in piston engines, then it becomes exciting. Anybody can do aerobatics in a robot airplane, not many can do it flying by the seat of their pants". One forthright spectator was rather more direct: "Not to sound too jaded, airshows are boring. So many people getting drunk, spilling crap all over and clogging the flight lines with kids-on-shoulders; you can't take a lawn chair and watch from the comfort of an umbrella and a beer cooler like you could back in the 70's and early 80's".

Another spectator was disappointed that "safety and noise abatement demands restrict the variety and scope of show routines, only a given set of manoeuvres may be performed, and these hardly ever change, year to year. I would rather see simulated air combat manoeuvres, put up some rock-concert/football stadium screens with the HUD pictures being shown real-time, make everybody sign an insurance waiver against claiming any form of damages and do the display at some 'way-the-hell-out-there' airports". Interestingly enough, this is not an uncommon sentiment, albeit a minority.

This comment from another spectator in the USA: "Until the horrendous crash of the *Frecce Tricolori* at Ramstein in 1988, they treated their AM-339's almost like Lipizanner's, 'bowing' them and doing opposing loops from really low crossing starts with a solo through the middle and all kinds of neat stuff as well as their famous 'behind the crowds' openers. I would like to see more of this from U.S. teams. Challenging and different show routines and not so much formation 'arrow-roll-to-diamond-and-back' stuff. Precise it may be, but so is counting the holes in ceiling tiles".

Comment from another more 'gung-ho' type: "I for one KNOW I'm risking my life anytime I let a 400 mph aircraft within about half a mile of me and pointed in my direction, even if it eats dirt that instant. I would sign any waiver and consider it worthwhile. Let all the wimps listen to the news broadcasts about 'dangerous airshows' and stay at home!" Such comments, however, actually have no place in the professional airshow environment and should be carefully considered since it sums up one of the dangers for display pilots. Aware that spectators are becoming more demanding, pilots may go out and try to perform even more spectacular manoeuvres – its called showmanship and herein lies a potential trap for the display pilot and the airshow routine design.

It is obvious that the 'gung-ho' spectator category really has no understanding of the dynamics and risks involved – it is not a philosophy that can be accepted or practiced by organisers and display pilots. It would be unprofessional and totally unacceptable to design an airshow to satisfy the minority of spectators' hunger for sensationalism and an 'adrenaline rush'. Could it be that 'highly regulated' shows are safer? Could it be that some spectators come to airshows to subsidise their own need for an adrenaline rush? Could it possibly be that some spectators attend an airshow knowing that the high-risk environment is conducive to an accident or is this just pure bravado from the 'macho' spectator? Would the same sentiments have been expressed by this specific spectator after watching the Ukrainian Air Force's Su-27 plough through the spectator enclosure at Lviv in 2002 killing 86 and injuring more than 156 spectators? Not likely – such a cavalier approach to aviation and display safety would ring the death knell for airshows all over the world.

This change in emphasis by spectators is recognised worldwide – spectators wanting more entertainment from the airshows, more than just the standard manoeuvres that they have watched over the many years. In South Africa, at the Test Flight and Development Centre bi-annual "Fly-In", the organisers tried to do meet the increased entertainment demands of the spectators. In an effort to break away from staid old traditions and provide something different, HUD camera video was telemetered to large screens, miniature cameras installed in the cockpit were also use to transmit audio and video to a large sport screen providing the spectator with the closest form of realism by trying to put the spectator in the aircraft. Since the airfield is co-located on a weapons range, it is also possible to demonstrate weapon's releases and the firing of air-to-ground rockets and guns. At the 75th and 80th SAAF anniversary celebrations at Air Force Base Waterkloof (South Africa), a selection of 1 versus 1 choreographed air combat manoeuvres were flown at low level in an attempt to increase spectator interest in the core functions of military pilots.

Israeli Air Force wings parades used to provide fine examples of firepower demonstrations, providing the reason to "show-off" the air force, the equipment and the skills of the pilots. In the past, wings parades included a truly impressive airshow which included simulated air combat manoeuvres, mock-attacks using the joint forces and the firing of rockets, guns and missiles at static targets, all this against the backdrop of inspiring classical music. Spectators watched in fascination as the individual manoeuvres and counter tactics were flown, the use of chaff and flares adding to the realism – all this, just 500 metres from the display line! The experience is enough to guarantee enthusiasm and public support for the air force and establish pride in the country's military forces while simultaneously providing a never to be forgotten experience for the spectator.

In an effort to feed the demands of fare paying spectators, airshow organisers are attempting to improve on each airshow. At Dayton's airshow to feature Warbird Acts WWII, dramatic historical WWII re-enactments with explosive pyrotechnics ignited the 2002 Vectren Dayton Airshow. The past was brought alive for fans both young and old with TORA TORA TORA's Pearl Harbour re-enactment of that day which will live in infamy. WWII Warbird combat mission simulations acts also featured realistic, high-tech, crowd-thrilling pyrotechnics that took spectators into the heat of battle.

As Japanese fighters unexpectedly approached, airshow fans were transported back in time to 7 December 1941 with precisely choreographed flying, spectacular explosions, strafing, dogfights, realistic sound effects and a historic narration for a chilling recreation of the attack on Pearl Harbor. The presentation was dedicated to the men and women who lost their lives at Pearl Harbor and in WWII. The Japanese Zero fighters flown by the Commemorative Air Force were expertly crafted replicas featured in a number of motion pictures including "Tora! Tora! Tora!", the "Final Countdown," and "Battle of Midway". A B-17, B-25 and P-51 simulated a WWII combat mission complete with riveting bombing and strafing runs. The climax of the mission was the B-17 simulated attack releasing a 2,000-foot "Wall of Fire" which increased the intensity as the "field of heat" and the aftershock, similar to a small earthquake, shook the airfield. Such realism takes the spectator as close to reality as possible, it keeps young and old, male and female, fascinated – all prepared to return next year.

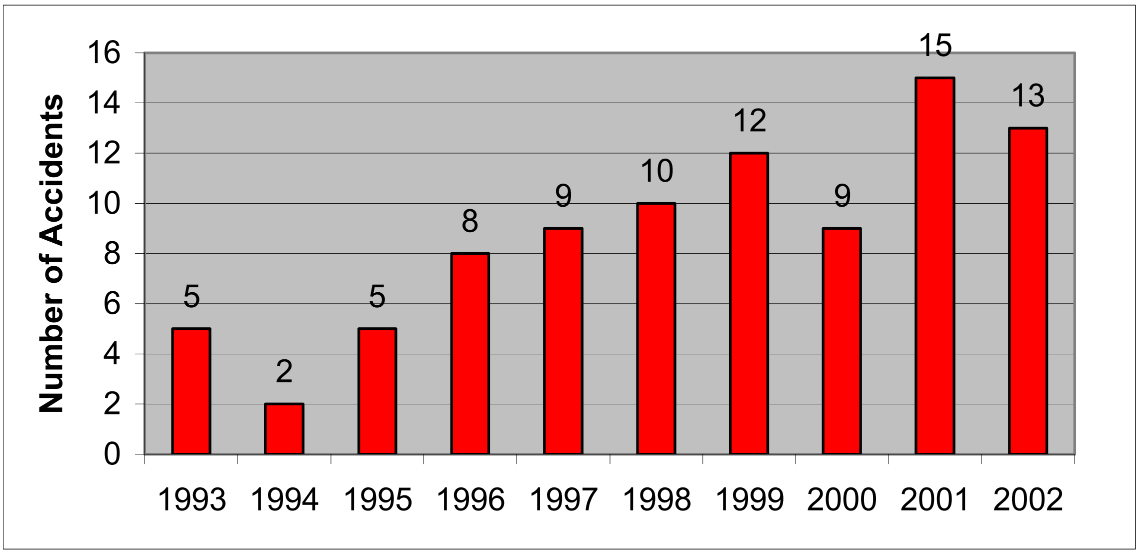
Given the hazards inherent in display flying an aircraft in close proximity to the ground, as in most dynamic sports, the risk of an accident is always present, much as in motor racing. The question can rightly be asked: "how safe are airshows for pilots, spectators and the public?" What risks are involved? Statistically, what are the probabilities of an aircraft accident at an airshow?

SPECTATOR SAFETY

Although there were earlier airshow accidents in which spectators were killed, the major safety watershed, which had a significant impact on the world of airshows and safety regulations, was the tragic crash of the Italian Air Force's *Frecce Tricolori* at Ramstein in 1988 - sixty people were killed and hundreds more injured. This put a completely new perspective on safety regulations and the rules for displaying aircraft to the public. This was the first year that the hazards of airshow flying were really brought home in such dramatic fashion, not only to the display pilots worldwide, but also to the aviation regulatory authorities and the public.

Three members of the Italian formation aerobatic team, Frecce Tricolori, collided during an airshow at Ramstein (Germany) killing sixty people and injuring several hundred more when one of the aircraft crashed into the spectators. (Robert Stetter)

Certainly, there have been several other airshows in which spectators were killed, twenty-eight spectators killed and sixty-three injured at Farnborough, UK, in 1952. Eight spectators were fatally injured at the Paris Airshow in 1967 when a Fouga Magister of the *Patrouille de France* failed to recover from the 9-ship bomb-burst, the crash debris falling amongst the spectators. Again at the 'Flanders Fly-In' at Ostende, Belgium in 1997, the Royal Jordanian Falcons solo crash killed eight spectators and injured dozens more, a stark reminder to the fallibility of the human being and the realities of the hazards of display flying. Although disastrous, certainly not the first and definitely not the last airshow accident at which spectators would be killed. In most countries, spectator safety at airshows receives the highest priority in the planning of the airshows but as in all systems, none are perfect and accidents have occurred in the past with horrendous results. Just when airshows worldwide appeared to have achieved a standard in



Random sampling of the number of airshow accidents worldwide over a ten-year period extending from 1993 – 2002. (Refer Chapter 3 for specific detail of each accident) which the safety of spectators was no longer jeopardised by display line incursions, the Ukraine Air Force Su-27 crashed into a spectator enclosure at an airshow killing eighty-six people and injuring 156 making it the most devastating airshow in the history of the airshow circuit.

Regulations of course, can only go so far – the introduction of the human into a highly dynamic, high-energy environment complicates issues. Even though accidents at airshows do occur, airshows still offer a consistently and historically safe environment for millions of spectators each year. Since current rules were implemented nearly fifty years ago, there has not been a single spectator fatality at a North American airshow, an enviable safety record for any business. Europe and the rest of the world have however, not been as successful, but considering that approximately 125 airshows of one type or the other are presented annually in the UK, similar impressive spectator safety statistics do actually exist for the UK.

Within the scope of an analysis conducted on airshow accidents worldwide since 1952, (Chapter 3), 703 (66%) of the accident victims were spectators in which 202 were killed and in excess of 501 spectators were injured while attending airshows. During the same period, fourteen members of the public were killed and 100 injured at airshows worldwide. Analysing a random sample of airshow accidents worldwide over a ten-year period extending from 1993 to 2002, a total of at least eighty-eight accidents were recorded. What is significant is that there appears to have been a significant increase in the trend in the number of airshow accidents since 1996. The year 2001 was the worst year by far with at least fifteen accidents while at the same time, quite ironically, the 2001 airshow season in the United States was the safest in the history of US airshows. Although statistical averaging has no specific significance in the analysis, it is instructive to note that the average number of airshow accidents worldwide since 1996 has been an unacceptable ten accidents per year, a trend that cannot be allowed to continue without significant adverse effect on the future of airshows.

The relatively high accident rate of display aircraft outside of the United States during the 2001 season, coupled with the totally unrelated September 11 terrorist tragedy in the United States, gave rise to an unprecedented increase in the threat to the survivability of the airshow world. The drastic increase in insurance rates, not only for the aircraft owners, but also for the show organisers and the requirement to improve anti-terrorist security, adversely affected civilian airshow organisers that eventually led to the cancellation of several smaller airshows worldwide. The costs could have been carried over to the public but that would have consequently resulted in a major decrease in attendance with all the negative spin-offs such as sponsorship withdrawal and cost overruns.

Poor decision-making and the susceptibility to making errors of judgement, especially in pressure situations, has resulted in some near misses and then also some of the most dramatic airshow accidents. All too often throughout the history of aviation, spectators have witnessed airshows and aerial demonstrations of aircraft that ended in destructive manoeuvres and the loss of life and aircraft.

The dramatic ejection of the Russian test pilot from the MiG-29 ‘high alpha’ fly-by at the Paris Airshow in 1989, the crash of the Russian Tu-144 in 1993 and the Sukhoi Su-30 MKI at the Paris Airshow in 1996, brought the total number of Russian aircraft display accidents at Paris to three. This kind of high profile failure made it very difficult for the aviation world to develop confidence in the Russian pilot’s display discipline, equipment and skills and presented the “worst nightmare scenario” for the Russian aviation industry at large. The synchro-pair of Russian MiG-29s colliding with each other at RIAT Fairford in 1993 and the spectacular in-flight structural failure of the Northrop F-117 in September 1997 in Baltimore, Maryland, USA and many more, have all brought the realities of display flying hazards directly to the spectators and the public in general.

Accidents at airshows are relatively infrequent, but do happen – wherever man and machinery are involved, there are risks; the major cause of accidents remains man’s fickleness and weakness in making sound judgement while operating such machinery in a highly dynamic environment.

It is an accepted fact that flying an airshow is high-risk, which means that the ‘primary task’ is risk reduction. Throughout the aerospace world, risk reduction has usually been achieved by engineering as much as possible of the aircraft and associated systems for pilot safety, obviously within the desired mission of the aircraft. However, airshows represent an exception to the ‘primary task’ rule of thumb because, given the accidents in Ukraine, Ramstein, Ostende and elsewhere, they may subject innocent bystanders to possible injury and death, for no particular reason.

Consider if you will, the millions of spectators attending airshows annually versus the number of people killed at airshow crashes. Then run some numbers for other incidents such as airliner crashes and even automobile crashes. A bad example? It’s like this though. People driving or flying from A to B are not doing so to be entertained and are generally not enticed into doing so with the promise of entertainment, nor is the event of driving directly staged or organised along the lines of a calculated risk.

A much better comparison would possibly be with other events in which machines are displayed for the public’s entertainment, typically, motor racing, boat races and so forth. In these cases, the risk of death is also relatively low. The question then is, “should all such events that unnecessarily risk death or injury to the spectators be banned? The answer can be yes, but only if it is proposed that ALL such activities are banned. Millions of people attend airshows each year, they know and accept that there is a small but finite risk as a result of this activity just as skiing, cycling and roller-skating carry risks. In a legal sense, they sign no waivers.

On the conclusion of the USA airshow season in 2001, the Charlotte (NC) Observer newspaper released a report indicating that since 1990, a total of 29 spectators and 231 drivers had been killed in automobile races. During that same period, 42 pilot deaths were recorded in airshows in the United States and Canada, but with no fatalities among spectators. “Though airshow safety has demonstrably improved over the last ten years, our entire industry recognizes that there is still important work to be done in this area,” said ICAS President John Cudahy. “We all look forward to the day when the safety record we had this year becomes the norm rather than the exception.”

The philosophy that puts the risk on the customer may be accepted but actually, it flies in the face of legal doctrines including, occupational safety. The people who attend airshows are not told of the possibility of an accident. Many activities such as mountain climbing, hiking, skydiving and playing contact sports are much riskier but its is not suggested that these activities should be banned, nor as hikers and climbers would they want to see them banned. The reality is that nearly all hikers and climbers make a conscious choice of actively participating whereas the attendees of airshows regard themselves as spectators to be entertained – but it is a case of conscious choice.

It wouldn’t be expected of a movie theatre audience to be put at a small or even unnecessary risk. The airshow audiences are just like movie theatre audiences in this regard, they are not

On 4 June 2001, the Spitfire pilot reported an on-board fire and turning back for a forced landing on the airfield, lost control on short final after taking evasive manoeuvres to avoid a group of spectators that had encroached the emergency landing area, auto-rotating into a fireball on the airfield. (François Henriot)

expendable. What if a fire breaks out? Not everyone will ‘exit in an orderly fashion’, someone could be trampled on or even smothered. Although a moviegoer is not constantly thinking about that when at the theatre, it is nevertheless always a possibility - just like the remote likelihood of an airshow crash. A large theatre chain probably does not have the financial muscle like government’s do to cater for the litigious modern society.

Is this akin to the lady who sued the manufacturer of the smoke detector? She took the batteries out of the device to power her ‘portable radio’ and her house subsequently burnt down. She sued because there was no warning label on the detector saying it wouldn’t work without batteries! It seems that in the modern world we try harder and harder to legislate ourselves away from having to use common sense, because it’s growing LESS common. The people who attend airshows are not told of the possibility of an accident, but nor do they need to be, just as nobody tells one of the possibility of getting struck by lightning every time there’s a storm, either. With the spate of liberal political correctness, a litigious society and personal freedom, it is not considered too far-fetched for someone to be struck and then sue a TV weatherman.

Spectators don’t sign waivers when arriving at theatres or airshows, nor do they when entering a grocery store, boarding a bus or playing a game of soccer in the park. There was a time when adults were expected to inform themselves to some degree. The people who attend airshows are not told of the possibility of accident, however, the airshow programmes all have significant sections in them explaining the safety rules in place. The commentators make a point of asking people to stay in designated areas and behind the tapes that delineate the safe zones. Theatres have burned down in the past, rows of seats have collapsed and people have died of heart attacks in movie theatres. In fact, it is doubtful that there is ANY difference in the statistical risk of attending an airshow in the US or UK and a movie theatre.

At the other end of the spectrum, there are still display pilots who lack that bit of maturity which enables them to understand the criticality of spectator safety, that understand the potential of a jet aircraft’s power without having to prove it to the innocent spectators. Spectators love to be thrilled by low-flying, but, there is a limit to just how low. On 21 June 2001, a SAAB Viggen jet swept very low over a group of spectators watching the display at the airport near Uppsala, 60km north of Stockholm military airport in Sweden. The aircraft passed so low overhead the spectators that six of the spectators on the ground suffered burns, three of them seriously. Officials did not say how low the aircraft was flying, but a news release from the air base said a group of seven people was watching the exhibition at a distance of about 75 metres from the runway.

Christer Ulriksson, a spokesman for the air force's F16 wing in Uppsala, said the injured were three men and three women, all in their 20s. “Three suffered serious, but not life-threatening burns”, he said. The injured were taken to the Akademiska Hospital in Uppsala and one woman was quickly released, spokesman Claes Juhlin said. The other five remained in hospital, with one woman in a very serious condition. “She was not so badly burned, but was thrown to the ground by the shockwave and suffered another serious injury,” Juhlin said. Ulriksson did not know exactly how low the aircraft was flying but speculated that it could not have been more than 20 metres above ground level, judging by the injuries.

In all likelihood, to inflict burns, the Viggen would have passed by at a height more like five metres. He said the distance of the injured people from the runway did not violate airport rules but was “inconveniently close”. It was not clear why the aircraft flew over the group at such a low height, Ulriksson said. “We do not know why. But we know the members of the group were acquainted with the pilots of this wing so he may have wanted to give them some sort of extra salute,” he said. This incident led to a Police investigation. (Associated Press)

PUBLIC SAFETY

Now there are two very distinct areas that relate directly to airshow safety, particularly with regard to the spectators and public. The first, crowd protection, was addressed worldwide a long time ago by the introduction of display minimum safety distances and minimum heights. The second, has never been adequately addressed anywhere in the world and it directly concerns the safety of people and property in the peripheral areas that surround a show site. This includes all people and property that must be overflown by aircraft as they manoeuvre and stage for their flight path parallel to the show crowd. Even when the 1500 feet ‘stand-off’ line is observed, there are risks in the turn-around areas. Aircraft in these areas are being flown at maximum performance, many times at the corners of their respective flight envelopes.

In the case of aerobatic teams such as the *Thunderbirds* or *Blue Angels* , a maximum effort is made to avoid inbound and departing flight paths directly over developments and heavily populated areas. Even then, after viewing the area maps and carefully planning each available show line, the inbound and outbound line and a show centre point for the team lead must be selected. In most cases, this will be a runway that meets the distance criteria from the crowd. The problem is now, and always has been, the 'fringe' areas. It's not enough to say that people shouldn't live within a certain distance of an airport, but unfortunately, that argument seems readily available to some who like to debate such issues.

No more was the hazardous reality of display flying more dramatically demonstrated and international attention to airshow safety more publicly scrutinised than the accident on 28 August 1988 in Ramstein, West Germany. (Robert Stetter)

There IS danger there, and to be quite frank, time and time again pilots and airshow organisers have taken an active part in FAA and military discussion groups that have tried to address these issues – the bottom line is that there is no easy answer. Most display pilots may never have broken the crowd rules, but make no mistake about it, during turn-arounds, the pilot and the aircraft are often 'maxed-out' in the peripheral areas on both sides of the show line - and there are houses and people below the aircraft all the time.

Collateral damage is often a result of an airshow accident. The hazards facing spectators at airshows are generally known and regulations are imposed to address spectator safety, however, in the case of the general public not even involved with the airshow, there is no elegant solution. The concerns by inhabitants of housing estates around the airfield are certainly well founded with added housing insurance implications. The area in and around an airfield being used for an airshow is at risk to collateral damage in the event of an aircraft crashing outside of the airfield. In an analysis of airshow accidents, fourteen members of the public were killed and one hundred were injured – members of the public that just happened to be in the wrong place at the wrong time, were killed or injured by airshow crash debris.

The innocent bystanders, the public killed or injured by collateral airshow accident damage, is pertinently illustrated in the case of the Tupolev Tu-144 accident at the Paris Airshow in 1973 in which nine members of the public were killed and sixty injured by crash debris coming down on the village of Goussainville, a few miles from the Le Bourget airport. There was also the case of the Indian Air Force Mirage 2000 crash in Delhi (1989) which not only claimed the lives of two spectators, but also injured twenty members of the public outside the airfield. The USAF F-117 catastrophic in-flight break-up at an airshow in Maryland, USA during September 1997 resulted in injury to four members of the public and also to several homes.

In October 2002, two Indian Navy IL-38 maritime patrol aircraft in formation practicing for an airshow to mark the 25 th anniversary of the Indian Navy's 315 Squadron, collided in mid-air in the western state of Goa killing fifteen people. One of the aircraft impacted on a road and the other on a building construction site killing all twelve aircrew while crash debris killed three labourers and injured seven.

These issues of collateral damage will never be able to be satisfactorily addressed. The shows will continue because people want them and because in reality, there is really no way to solve the ultimate safety issue concerning the peripheral areas. People will always buy property next to an airport and some will move away but construction developments will continue and little will change. Pilots who, after viewing the aerial photograph of the display area and attending the safety meeting, choose the 'best available' approach and departure flight paths to avoid the populated areas as much as they can, and still arrive at the show line with the required combination of airspeed, altitude and g.

The realisation of the hazards have not gone unnoticed by the airshow performers, particularly those in the military. The seriousness and commitment with which professionals have had to 'up' their attitude to zero accident tolerance display flying can best be illustrated by the example in which the United States Navy's *Blue Angels* suspended their demonstration programme because the team's leader was concerned about his own flying performance. Cmdr Donnie Cochran, 41, did not want to jeopardise the safety of the team's pilots and decided to take his team back into intensive training after lining up above the wrong runway during a high-speed, low level manoeuvre at Oceana Naval Air Station in Virginia Beach, VA, on 23 September 2001.

One of the heart-stopping manoeuvres in front of a crowd of 150,000 required four aircraft to cross over a single point simultaneously from different directions, using two runways as their 'marks'. Cochran approached the point over the wrong runway, the other pilots saw that he had made a mistake and adjusted to it. The prudent question is: "In that particular manoeuvre, was safety impaired?" Well, it could have been, but wasn't necessarily. Part of professionalism is being able to recognise an incorrect/unsafe situation and with all formation members situationally aware, compensating adequately to recover from the impending crisis situation.

The kind of self-evaluation leading to making such a public decision is pretty rare these days when the pressure is to 'do at all cost' and represents its own special brand of courage. Bearing in mind that a total of 22 *Blue Angels* pilots have been killed while training or performing since the unit was formed after WWII in 1946, the hazards and traps are well understood by the pilots. From this, it appears to be a gutsy decision made by a mature leader.

No analysis of airshow safety would be complete without considering the impact of the environment on safety at airshows. In this specific case, inherent in the nature of low level flying demonstrations, lies the risk of birdstrikes that will continue to remain a real threat to low-level flying aircraft, being even more critical in the presence of spectators. In April 2000 'Wild Bill' Marcellus suffered a 'too-close encounter' with the ground at the Barksdale AFB Base, Louisiana Airshow. Marcellus was nearing the end of a high-energy routine when he hit the ground with enough force to bend the aircraft's undercarriage. He was flying at nearly 200 mph about 30 feet off the ground when a bird apparently flew into the Edge 360's propeller. The aircraft hit the grass field and bounced back into the air before Marcellus was able to set it down. During the 1999 SIAD airshow at Bratislava, Slovakia, held on the 5 June 1999, two of the *Frecce Tricolori* aircraft ingested birds into their engines during their display, fortunately, both the MB339s were both able to land safely.

Protection of the public is a critical element of airshow and display flying safety and is universally acknowledged as a priority by participants and airshow organisers alike. However, even though every effort is made to make the shows as safe for the spectators as is humanly possible, the ultimate answer about the safety of the peripheral areas will remain. So, what is the major threat to improving airshow safety?

HUMAN ERROR

Making an error of judgement is not the sole domain or copyright of a certain individual, group or category of pilots. There is no display pilot that has survived the airshow circuit that cannot tell of 'close shaves' – most pilots have had incidents in which their own skill and judgement had let them down during their display careers which, but for the grace of 'Higher Authority', would have killed them. In the high threat environment of the low-level display arena, the use of the term 'pilot error' is not really considered appropriate and the term 'human error' seems to be more semantically correct. Unfortunately, the term 'pilot error' implies negligence whereas the term 'human error', more accurately captures the realities of display flying errors caused by the fallibility of the pilot to judge, estimate and anticipate accurately and consistently.

Heads of State often make mistakes or poor decisions, top surgeons have been known to amputate the wrong body part, general managers of international companies have caused the collapse of companies while accountants have made calculation errors ending in bankruptcy or the loss of millions of dollars. The bottom line is that every human is generally a weak decision maker, especially under stress. In the flight display realm, such stress may best be exemplified by 'life-threatening' factors like finding oneself at the top of a low-level, vertical manoeuvre with insufficient height or airspeed to complete the manoeuvre, or an excessively large 'nose-drop' while performing a low level aileron roll.

In some professions, one is able to hide or even cover up mistakes. However, in display flying, it may well be the irrevocable 'point of no return' that has been passed; there is no second chance. No excuse or hastily prepared political statement can put the record straight or negate the disastrous effects of an aircraft accident at a flight demonstration or airshow; the public outcry similar to that in the United Kingdom during June 2001 following a spate of three accidents, cannot be wished away. Two accidents at Biggin Hill and one at Paris over three consecutive days in June 2001, provided the "nightmare scenario" for the airshow world. But airshow accidents happen even to the most professional aerobatic teams such as the USN *Blue Angels* , USAF *Thunderbirds*, RAF *Red Arrows* and the Canadian Air Force *Snowbirds* , not to mention air forces and general aviation professionals worldwide, have all suffered losses due to accidents.

The concern is that "errors of judgement" are not made on purpose but almost invariably result in an aircraft accident with, our without loss of life – there is no "second chance", there is not another opportunity to stop and then start all over again – like other professionals that would get an opportunity to maybe start a new career. Nevertheless, the fact of the matter is that statistically, approximately 67% of all aviation accidents, military and civilian, are caused by human performance errors. The display pilot community has not escaped these damning statistics, and the case studies presented in this book are particularly indicative of the fallibility of the human. Approximately 79% of all airshow accidents are attributable to MAN in one form or the other. The difference of 12% between general aviation's 67% and airshow accidents' 79% is indicative of the increased hazards existing within the low-level display arena. The remaining 21% being attributable to 'mechanical' and 'environmental' factors.

Historically, the safety statistics of airshow and aerial demonstration accidents are relatively disappointing, but considering the dynamics of manoeuvring an aircraft at very low level, this is not surprising. Although no accurate figures are available for display and demonstration accidents since the start of aviation, from random statistics available since 1952, more than 401 lives have been lost and more than 673 people injured in at least 118 random airshow accidents at a cost of more than 1 billion dollars in aircraft. In the final analysis, a display accident, excluding mechanical failures and environmental effects of course, can only be blamed on "human error", whether it be pilot's response/reaction time, anticipation, technique or situational awareness – these are the weak spots in the human physiology. It is essential for display pilots to made aware of their shortcomings in this regard and for training to focus on strengthening the deficiencies – however, it is not possible to completely eliminate such deficiencies in the human physiology, the best we can hope for is to reduce the error margin through training.

The irony of air display crashes is that the pilots involved are professionals and in most cases, have a considerable amount of experience. Experience ranges from highly experienced combat fighter pilots, highly experienced test and demonstration pilots and world aerobatic champions to professional airshow pilots with more years and more hours experience than most people care to remember. Charlie Hillard, 58, who was killed in a Sea-Fury accident in 1996 at the Lakeland Fun 'n Sun, had logged 42 years and more than 15,000 hours of flight time. Wayne Handley, a former Naval Aviator, aerobatic champion, 'ag' pilot and aerobatic instructor amassed a phenomenal 25,000 hours of manoeuvring time in his 43-year aviation career before being injured in an airshow accident flying an Oracle Turbo Raven at the California International Airshow in 1999. His aerobatic ability earned him the title of California Unlimited Aerobatic Champion, not once, but three times. In April 1999 flying a G-202 he increased his own world record for inverted flat spins to seventy-eight turns. In 1996 he was presented the Bill Barber Award for Showmanship and in 1997 the Art Scholl Memorial Showmanship Award, two of the most prestigious awards in the airshow industry. The 54-year old 'Hoof' Proudfoot was another very highly experienced airshow pilot with 14,500 flying hours that died in a P-38 airshow accident at Duxford in 1996. Considering the vast experience of those display pilots killed in airshow accidents, the only logical conclusion that can be reached is that experience alone, is not enough to guarantee survival on the airshow circuit.

Most, if not all pilots displaying an aircraft in public are very experienced pilots, but accidents happen, for whatever reason. In the military, display pilots must have a significant amount of experience on type. However, on privately owned aircraft, the regulatory stipulations are less severe and demonstration pilots may not necessarily have many hours on type. The fact that they own the aircraft and have the necessary licence to demonstrate an aircraft, does not mean that they are totally 'au fait' their acquisitions, in fact, they may, in all probability be slightly short on the experience necessary to provide a low-level aerobatics display.

An interesting observation is that all pilots involved in display flying, fixed wing or rotary wing, have demonstrated a characteristic passion for aviation, in particular, display flying in one way or another. Whether it is in rebuilding a vintage type aircraft, having display flying as a hobby, or being active within the airshow administration business, they have devoted their lives in pursuit of their passion. Display flying demands more from the demonstration pilot having to travel all over the world or country from airshow to airshow displaying the aircraft. In many cases, display pilots have to sacrifice family ties in some cases during the airshow season, wives becoming 'airshow widows', even literally in some cases. Moreover, as in most things in life, this passion is only given recognition posthumously. In a statement following the fatal crash of the Vampire at Biggin Hill's Air Fair 2001, the family of Mr Kerr said: "Jonathan was a very special person, who lived for his passion and died living it. He worked hard and achieved his ambition to reassemble and fly his own Vampire."

A similar eulogy was echoed by Tom Poberzny relating to his old time friend and fellow airshow pilot, Charlie Hillard who was killed when his Sea-Fury flipped over onto its back during a landing at EAA Lakeland Sun 'n Fun '96. Some of Hillard's accomplishments included Member U.S. Skydiving Team 1958, National Aerobatic Champion 1967, World Aerobatic Champion 1972, Leader of the *Eagles* Aerobatic Team 1971-1995 and EAA Oskosh airshow boss 1991-1995. Total commitment to the cause of display flying and the airshow circuit, if ever there was.

Poberezny said that: "Charlie Hillard was a world-class aviator. He was a world aerobatic champion, the leader of the *Eagles* Aerobatic Team for 25 years. He was just totally immersed in aviation. Along with his aviation skills, Charlie was a highly respected member of the community, as evidenced by the outpouring of support to his family and colleagues in his hometown of Fort Worth, Texas. He was also an important part of the EAA family. That makes this an especially difficult loss from both a personal and professional standpoint". Such accolades could no doubt be directed at most other display pilots, a total commitment.

An interesting observation from the SAAF's airshow safety liaison officer, Lt Col 'Rocky' Heemstra regarding the types of pilots selected for display flying and the relationship to human error is that display pilots generally tend be chosen for their ability to fly the aircraft near the limits of the manoeuvre envelope. A conservative 'by-the-book' pilot hardly ever seems to be chosen as the display pilot. This is possibly a natural consequence resulting from the nature of display flying and is also the preferred profile of the display pilot by airshow organisers, competition judges and/or the Commanding Officers who prefer the pilots to display the aircraft at or near the edge. In essence, the display pilot selectors tend to choose aggressive pilots to become display pilots. Mind you, not necessarily aggressive personalities, but rather aggressive aviators - pilots who are prepared to put the aircraft into attitudes necessary to guarantee the safe execution of the specific low-level task.

Although safety margins are included within an aircraft's certified flight envelope, once a display pilot survives a manoeuvre near the edge of the envelope, this particular manoeuvre then becomes standard and each time it is flown and survived, a conditioning factor is applied. The next time, the envelope is pushed a little bit further. Each time the pilot survives, the previous manoeuvre boundary becomes the baseline and the next time it is pushed a little further. Include the pilot's ego plus the airshow pressures of displaying the aircraft to the public, then even the most experienced pilot will get caught and fail from time to time.

A display pilot doesn't just make an error, there is always some mitigating factor, some contributory cause that seduces the pilot's natural instincts, his peripheral cues, that overwhelms his information processing powers or anticipation, ultimately causing judgement errors. The challenge to improve airshow safety lies in an awareness to educate display pilots with respect to their, and the human's fallibility in decision making, anticipation, response, discipline and training.

Comment on airshow accidents from a former leader of the *Thunderbirds* : "Every time I hear of an aircraft accident, be it airshow, airliner, general aviation or military, I pray the cause is "Human Error." Why? Because as a pilot, it is the only thing I have complete control of. I cannot control engine failure, parts malfunction, poor maintenance or eventual structural failure other than flying the aircraft within its design limits. Even then, it could be a 'crap shoot' if others have been overstressing the bird. The solution is professional training according to an approved syllabus, reasonable rules and regulations, a safe show line, proficiency and solid air discipline. Of course, a well maintained aircraft is imperative. Each one of these factors is as important as the other. This is common sense and we all know that. Now let's just do all we can to ensure compliance. Accidents do happen but it should not be due to gross negligence on anyone's part. We CAN fly an exciting and entertaining airshow safely and professionally".

IMPACT OF AIRSHOW ACCIDENTS

From the time of Wilbur and Orville Wright, in fact, even from as early as the infancy of flight, mankind's early experimentation with lighter-than-air vehicles has produced accidents. Nothing much has changed, except the date. Aircraft accidents at airshows are not a new phenomenon, they have shocked and fascinated the spectators and general public since the first flight demonstrations. In fact, the first female aviator killed in an airshow accident occurred on 1 July 1912 as pioneering aviatrix Harriet Quimby (35) and William Willard, a friend, died when their Blériot fell out of the sky during an airshow over Dorchester Bay, south of Boston, Massachusetts. Quimby had been the first woman to fly solo across the English Channel and was the fourth woman flyer to be killed in an aviation accident.

Aerobatic flight, a specialized area of general aviation, is commonly defined as "precise manoeuvring in three-dimensional space," which should be considered in terms of three components, ie. position, velocity, and attitude. An aerobatic aircraft's position should be precisely controlled about all three axes of pitch, roll, and yaw and can be quickly reoriented to any other position through manoeuvring. Lincoln Beachey is widely recognized as the "father" of aerobatic flying, even though his feats were, at first, dismissed by none other than Orville Wright as mere "optical illusions." All such doubters were converted during a now-legendary 126-city barnstorming tour in 1914 when Beachey, known as "the flying fool," dazzled crowds across the USA flying stunts in his aircraft, the *Little Looper* and even Orville Wright retracted his original comments, describing Beachey's exhibitions as "poetry."

An airshow accident is a disaster in more ways than one; the negative publicity generated conjures up an emotional response from the public. If the aircraft is a military aircraft, the taxpayer's pocket is directly affected since the loss of a valuable military asset at an airshow, which is not even a military role or function, cannot be considered or accepted as normal attrition to a "fighting force".

Bearing in mind that airports, airfields and military bases are invariably surrounded by built-up residential areas and the collateral damage caused by an aircraft crashing on, or off the airfield, can and has produced very distressed responses from local residents. The formation of 'liberal lobbies' grouping together advocating the end to airshows or even worse, the closing of an airfield or airport, is a reality.

An airshow accident is always very sad and unfortunate, but as everyone, including all the top professional display pilots know, the only way of achieving a zero accident rate for airshows is to suspend all low-level aerobatic flying. In fact, the air forces around the world would be well within their rights to do this since they are an operational Service protecting the national security of their citizens, not just to show off. There is an old saying however, which just about sums up aviation safety: "Insisting on perfect safety is for people who don't have the balls to live in the real world."

At the Biggin Hill Air Fair over the period 2 to 3 June 2001, two displays went horribly wrong. On the first day in front of a large crowd, a De Havilland Vampire 'flicked-in trailing in the wake of a De Havilland Sea-Vixen during a tight turn at low-level. The very next day, a vintage P-63 Kingcobra 'spun-in' from the top of a low-level loop. Two pilots and a passenger were killed in two separate airshow accidents within twenty-four hours. Still recovering from the astonishment of the previous two consecutive day's accidents, and in the face of ongoing questions and criticism from the public and media alike, television footage portrayed the shocking images of the Spitfire crash in Paris on 4 June 2001, only one day later. The pilot reported an on-board fire and turning back for a forced landing on the airfield, lost control on short final after being forced to take evasive manoeuvres to avoid a group of spectators that had encroached the emergency landing area, ultimately auto-rotating into a fireball on the airfield.

The first demonstration flight fatality in history occurred in 1908 when Lt Thomas Selfridge was killed in this aircraft piloted by Orville Wright. The accident wascaused by propeller separation. Orville Wright suffered broken ribs, pelvis and a leg. (17 September, 1908)

After a weekend at Biggin Hill Air Fair where one aircraft crashed just short of the runway to be followed by another on the airfield itself a day later, a resident of the area could be forgiven for seeing the location as one of significant danger. As an urgent priority, the neighbourhood must be reassured that there is minimal cause for anxiety (BBC On Line)

Public shock at the catastrophic accidents was widely published in the media, a not unexpected reaction considering, but questions had to be asked about the safety of airshows. More particularly, the impact on public safety and the wisdom of displaying vintage aircraft in flight at airshows over built-up residential areas was criticised. The question asked was: "Why not keep such valuable vintage aircraft on the ground for static display only?" In the Biggin Hill aftermath, the organisers were stretched to reassure the public and contain any public relations damage.

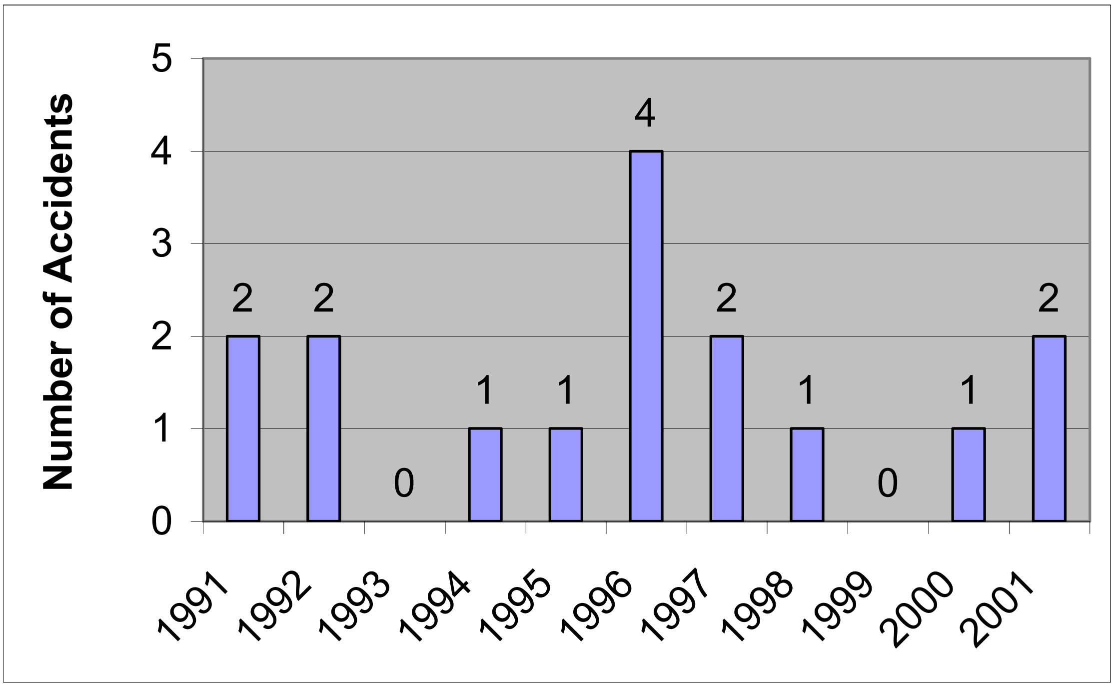
Official word from Jock Maitland who organised and ran the first International Air Fair at Biggin Hill in 1963 was: "When the first International Air Fair was planned, had I known that we would one day lose two pilots and one crew member in a single weekend, it would never have got beyond the planning stage. Seventeen years later in 1980, when a display pilot and crew were lost at a 'Battle of Britain' day here flying a vintage A-20 Havoc, everyone concerned was so badly shaken by the tragedy that it is still frequently mentioned and discussed".

"It is necessary to understand the traumatic effect of the weekend's disasters and why it is necessary to accept them in proper perspective to the overall performance of one of the most popular family entertainment forms in the United Kingdom. Our first thoughts and prayers are for the three men who died and for their bereaved families and friends. Both pilots had spent their adult life flying in peace and war, it is perhaps some comfort to know that they died following their chosen way of life".

"That said, as a community event with most supporters being local people, we have to try to understand and consider how they see themselves as being affected. This applies particularly to those living very close by, many in sight of the airfield. The airport is one of the busiest in Europe and the annual International Air Fair has become world famous attracting the latest and fastest civil and military aircraft. Statistics are so often used to support an argument that they do not by any means always convince, but it is an unarguable fact that the road past the airport is enormously more dangerous than the airport itself".

"Biggin Hill is the world's longest established airshow site with displays held annually since the 1920's. Two accidents are two too many, but compare extremely well with other spectator sports which will also never be completely safe. It is hoped that these two accidents can be put into perspective against the record at Biggin Hill and the country at large. It is a fact that not a single spectator or member of the public has been killed on or off an airfield during a flying display anywhere in the UK since the Farnborough Airshow on 6 September 1952 when twenty-eight spectators were killed as the De Havilland DH-110 disintegrated during a high-speed pass".

"It is the duty of the CAA to review on an ongoing basis, the safety of airshows and it will be quite proper that they do so after this weekend. There is no question that we will be looking very closely at our own Air Fair safety regulations and fully intend to address the concerns of our neighbours. There are about 125 air displays, large and small in the UK each year that will give pleasure to millions. This is well above the level of other countries in Europe and as safety regulations become increasingly international, our outstanding record is widely used as an



Over a 11-year period in the UK, a total of 16 fatal accidents occurred.

example. The high sense of responsibility of show organisers and the vigilance of the Civil Aviation Authority will ensure that an already highly safety conscious industry can only continue to improve."

That said, in the UK over the eleven-year period from 1991 to 2001, a total of sixteen fatal display accidents were recorded, the worst year being 1996 in which four fatal accidents occurred. There were only two years in which no fatal airshow accidents were recorded, 1993 and 1999. However, these statistics must be considered against the approximately 125 airshows and aviation displays held annually in the UK, making it at least 1,375 airshows over the eleven-year period. No matter how accidents happen, it's a sad event for all concerned, including the spectators, the show organisers, the other display pilots, the co-workers, friends of the pilot, and the family of the pilot. Adding the death of a spectator or a member of the public remote from the airshow, makes it even worse. It is a fact that airshow routines are hazardous which is often hard to realize when they're flown by highly skilled pilots who make it all look so effortless.

In the USA after the crash of an F-14 at Horsham in June 2000, several people questioned the wisdom of such events, but defenders said the shows are safer than other types of activities. Each man had more than 1,000 flight hours in the Tomcat, and both were assigned to the VF-101 'Grim Reapers' fighter squadron at Oceana Naval Air Station, Va. Their aircraft crashed in a wooded area off Horsham Road, just yards from homes and businesses but luckily injuring no one on the ground. Several local homeowners and businesspeople argued that the 'Sounds of Freedom' show should be suspended indefinitely while the tragedy renewed the debate on the real value of the aerial displays.

A commentator who had seen airshows from both sides, as Commanding Officer of the Willow Grove Naval Air Station in the 1960s, he helped organize the event, and as township manager a few years later, spoke about safety concerns. Under similar duress to that of the Biggin Hill Air Fair organisers: "I feel for the residents that have a problem with this," he said, echoing locals' safety concerns. "But at the same time you have to weigh that against the nett good that comes from airshows". You can't put this sort of thing into a formula. Now I just don't know what's going to happen." The Base's public affairs officer said they were reviewing the tragic events to determine whether the base should host the future 'Sounds of Freedom' Airshows.

A spokesman for Naval Air Forces Atlantic in Norfolk, Va., said the Navy had no plans to discontinue performances by Oceana's F-14 squadrons or to suspend airshows nationwide. This was the second accident in 2000. In March 2000, an F-16 Fighting Falcon crashed during an event at Kingsville Naval Air Station in Texas, killing 35-year-old USAF Maj. Brison Phillips. About 15,000 people watched as the pilot crashed attempting a split-S at low altitude.

Kingsville Mayor Phil Esquivel, said the accident, the first in that base's show history, was a tragedy for the community. "The crowd just went silent, people fell to their knees and cried but fortunately, the impact occurred almost five miles from the station's perimeter in an open field close to a few buildings and fortunately, no locals were injured in the accident. Both Kingsville, about twenty miles southwest of Corpus Christi, and Horsham, have about 25,000 residents, but Esquivel said the Texas town had large open areas around its naval station. "Safety-wise, we're very fortunate for that."

The day after a De Havilland Vampire "flicked-in" trailing in the wake of a De Havilland Sea-Vixen - the very next day the vintage P-63 Kingcobra "spun-in" from the top of a loop. (AAIB)

After the crash of the F-16 during the first day of the Kingsville Airshow, the rest of the weekend's events were cancelled, however, officials reviewed the tragedy and decided not to eliminate future airshows. The next one wasn't scheduled until 2002 anyway, but this accident would in no way affect that event, said Esquivel. "It's vital our armed forces be able to show the taxpaying citizens what their money goes for. It was very tragic, but we're staunch supporters of the base and we support the airshow 100%."

In the USA from 1990 to 1999, fifty-two accidents occurred at airshows, according to statistics from the International Council of Airshows, but council President John Cudahy said that the safety record, while unacceptable by its standards, was comparable to, if not better than automobile races, sporting events and nearly any other sizeable outdoor event. "Airshows are not what people suggest; they are not a continual series of funerals," he said. "But at every airshow, there are hundreds of video cameras ... and that can make for compelling footage." It is this media coverage of airshow accidents that brings the accidents into the homes of the general public and creates the negative perceptions.

Cudahy also noted that since 1952, when current airshow standards were adopted, no spectators, groundcrew or nearby residents had been killed in performance-related accidents. "Spectators feel they are protected because they are protected." Under FAA standards, airshow organizers must apply for permission to hold the aerial spectacles and set up viewing areas a sizeable distance from the flight zone. Performers may never point their aircraft towards the crowd, all manoeuvres must be parallel to or away from the crowd and civilian pilots must be certified by ICAS.

Dale Snodgrass, a former Navy captain and current airshow performer, said that the regulations kept the danger away from the spectators but directed it toward the pilot. “But we understand our risk and try to minimize it,” he said. “Foremost is to make sure never ever to put the crowd in jeopardy.” Snodgrass was airborne during the ‘Sounds of Freedom’ accident waiting for clearance to land and despite the tragedy, he said his resolve for performing had not been shaken, and that the public should not be scared away. “As airshows go, it’s one of the safest venues there is for spectators.” Still, all the airshow supporters admit the event does carry inherent hazards, with crashes a painful reminder. “Unfortunately, the ground is very unforgiving,” Snodgrass said.

Finally, the question raised by many airshow enthusiasts is: “Why do accidents happen at airshows, aircraft flown by some of the best display pilots in the world? In that case, how do airshow pilots react to airshow accidents, and what about the spectators? Well, in all truth, airshow accidents happen for the most part because airshow flying involves putting the aircraft and the display pilot in the maximum performance areas of the flight envelope at low altitude which is a potentially hazardous combination. Airshow flying and low altitude aerobatics in particular, can be a hazardous profession in which fatalities have occurred, and will continue to occur at these events, despite regulatory constraints.

For most pilots who have worked this life style, the emotional reaction to these crashes eventually gets replaced by a cold sort of withdrawal that allows them to evaluate the cause and learn from the experience while keeping their feelings to themselves and their close friends. This might sound a bit harsh, but remember, the pilots have to go do it again, ...the spectator doesn’t! Just to provide some perspective on this; imagine being asked to fly a display by the Flying Control Committee immediately after watching a colleague perish in an accident at the airshow.

Similarly in the case of the spectators, they are generally good people who just come out to watch and enjoy the show. Seeing somebody killed is the last thing on their mind. When it happens, there are children who become traumatized and lives can be virtually changed in an instant. There have been parents holding crying children, widows crying as they tried to come to terms with their losses because in most cases, wives and family of airshow pilots invariably attend the local airshows. The bottom line is that if you enjoy airshow flying, or motorcar racing, sooner or later you will return home after witnessing an accident. It is certainly not an easy business!!

AIRSHOW CRASH MANAGEMENT

In today’s world, being an airshow organiser has become a stressful occupation. The days of friendly family show days are past and as in all things in life, have been replaced by highly professional and competitive showpieces. Spectators have now become ‘paying passengers’ demanding more for their money and for show organisers, just breaking even financially, has becoming increasingly difficult. Not only is the airshow organiser responsible for providing the entertainment, but also the health and safety regulations demand strict enforcement and the provision of a safe environment, including accident and crash rescue services. Failure to comply with such demands can have devastating penalties for non-compliance, particularly the ‘worst-case scenario’ – the airshow accident and the management of post accident casualties.

The airshow world has been rocked by some grim accidents, and in truth, during the show planning, it is extremely difficult to predict the ‘worst case scenario’. Typical considerations are how many and what category of aircraft accidents can be handled by the crash and rescue services available at the specific display location? Just the logistics alone and the costs of providing adequate numbers of rescue and medical staff to handle a ‘worst-case scenario prediction,’ make it practically impossible to provide the all the resources.

Obviously, to provide the show committee with guidance during planning, the display regulations in place will be assumed to have been conformed with by the pilot and from that basis, each of the displays would have to be considered before attempting to predict the worst-case situation. In the calm of a planning environment, planners tend to forget the real world picture of panic and chaos following an accident, especially if the accident not only includes the aircraft, but also spectators or members of the general public remote from the display site.

Command and control requires excellent communications systems and well practiced crash rescue personnel equipped with the necessary tools to cover the entire spectrum of accidents and incidents from snakebite serum to the total range of intravenous drips. Airshow organisers at SAAF '80, the 80 th anniversary airshow of the SAAF held at AFB Waterkloof, relied extensively on cellular phones for communications but with approximately 220,000 spectators attending, the local cellular phone repeater stations were jammed by overload, rendering the communication network useless. During AAD 2002, also held at AFB Waterkloof, two more repeaters had to be installed to cover the incredible increase in cellular network coverage and alleviate the satellite communication's saturation.

Actually, it is nearly impossible for the airshow organisers to cater for the entire spectrum of possible emergencies, contingencies and mobile First Aid facilities. It is for this reason that all hospitals surrounding the display location are usually brought on standby to assist in handling emergencies outside the scope of the on-site crash rescue paramedic capabilities.

Then there are the evacuation facilities, helicopters and ambulances, the same questions must be answered in terms of communications, personnel, command and control and emergency routes. With the popularity of modern airshows, the numbers of spectators that could be injured has increased by orders of magnitude and in turn, the probability of many people being injured has also increased for accident scenarios while the logistics for handling major emergencies has increased far beyond what most airshow organisers and planners are able or prepared to commit to. Planners are loath to commit to worst-case scenarios due to the impracticality of implementation programmes and often find it rather easier to increase display regulations to 'cover their arses'.

It is instructional to consider the *Frecce Tricolori* accident at Ramstein in August 1988 as a case study of the real world of post crash management. Who would have envisaged a catastrophe of this order during the planning stages? Three AM-339 aircraft of the Italian Air Force precision aerobatic team *Frecci Tricolori* collided during the airshow at Ramstein AFB, Germany. After colliding with two other aircraft, the solo pilot's aircraft, heading directly for the crowd during the cross-over, crashed into the spectator's enclosure, killing approximately forty of the spectators during the first minutes and injuring several hundreds, mainly with burns.

The impact point was near the Army Medevac Huey that was on standby near the runway and killed an Army aviator. A British Medevac Puma crew that had all their kit spread out around their helicopter in the static display park, threw all their equipment back into the aircraft and immediately took off and started doing their job within minutes of the crash, surrounded by stunned spectators. Ironically, with all of Ramstein responding to the calls for blood donors, at the same time, there were Germans protesting against airshows outside the main gate.

After the immediate panic and escape, thousands of people tried to return to the site of the accident which made the rescue operation even more difficult. Fire fighting vehicles managed, with the help of rotating blue beacons and blowing horns, to reach the fire, which, when all the fuel had burned out, could be easily extinguished. A few minutes later, ambulances and helicopters arrived but because of all the noise, radio and telecommunications systems could not be used effectively.

The four "First-Aid" stations were obviously not equipped for an accident of this size and they only had a few litres of fluid. Injured people were instead spontaneously taken to three other defined areas for sorting and medical help before being transported to hospitals. The US military personnel evacuated the patients as fast as possible to hospital while only minor treatments were administered at the site of the accident. No infusions were given before the arrival at the hospital. Most of the activity was rather improvised and no one had a true picture of the actual situation, the injured were taken to several different hospitals. In Landstuhl, close to Ramstein, a well-equipped American military hospital accepted 120 patients from the accident, sixty of these, all German citizens, were transferred to other hospitals on the same day. More than forty patients were released from the military hospital the same day after receiving treatment.

Because of the great number of injured arriving at the hospitals, it was necessary to prepare surgery in advance in the emergency departments, more particularly tracheotomy and amputations. In Landstuhl, there was also a civilian hospital with 406 beds that received seventy patients, most of which were sorted in the ambulance hall. Seriously injured patients were taken care of by an anaesthesiologist and a nurse. Fifty of the seventy patients brought to the hospital were admitted but ten with severe burns were transported to Ludwigshafen which was a specialist hospital for the treatment of trauma cases with competence in orthopaedic, traumatology, intensive care, plastic surgery and burns treatment. This hospital received thirty patients with burns of which twenty-eight arrived within the first five hours after the accident; four patients died during the first hour.

In Kaiserslautern, there was a civilian hospital with special competence in traumatology and thorax surgery and altogether ninety-eight patients from the accident were taken there, forty-two of which were admitted. Injured people from the accident were also taken to other hospitals in surrounding towns. Besides that, several burn's clinics in Western Germany had prepared to receive patients from Ramstein but did not get any, at least not during the first days because the patients were preferably taken to hospitals in the vicinity of Ramstein. One day later, on 29 August, a medical team arrived from San Antonio in Texas to Ramstein to evacuate four patients with severe burns to Brooke Army Medical Centre in San Antonio. The death toll from the accident rose during the following two months to sixty-nine, of those injured, 50% had burn injuries.

In modern society, when considering medical support, airshow organisers must also consider the aspect of payment for medical services. Although there may be hospitals in the area, some private hospitals refuse to accept patients unless they are paid up members of that particular hospital or Medical Aid Fund. This was the case with AAD 2002 in South Africa. The airshow organisers had to be specific which hospitals could take the injured in the case of an accident.

Another less well-known case of poor airshow and crash management was the accident in front of several thousand spectators at the 'Africa Aerospace Airshow 1981.' South African aerobatic champion Nick Turvey recovered from a thirteen turn inverted spin but with inadequate height to affect a safe recovery pullout, the aircraft impacted approximately eighty metres behind the spectator showline in an open gully between the showline and the hangars. Miraculously the aircraft did not explode on impact and the no one was killed but Nick Turvey was hospitalised for several months as his badly injured body recovered.

This accident was marred by poor crowd control, the crowds surging forward to the crashed aircraft and hampering the rescue vehicles and para-medics. It was obviously never envisaged during the planning stages of the airshow that an aircraft would crash behind the crowd line. According to a witness at the time: "The show organisers clearly had no proper emergency plan in place, or they certainly didn't rehearse for it! From my own experience, I know how soon one forgets the drill when not practiced. No proper crowd control, no procedure (fire engine caught in the fence), too many spectators 'lending a helping hand' thus preventing the medic's from doing their job and no crew manning the emergency helicopter."

Although hospital and medevac planning and support will not prevent an airshow accident, it is an essential component of the overall airshow planning process – it is a foolish and irresponsible Organising Committee that will not prepare adequately for all emergency contingencies at an airshow.

AIRSHOW ACCIDENTS AND THE MEDIA

Following the world's worst airshow disaster in the Ukraine on 27 July 2002 where eighty-six people were killed and 156 injured when an Su-27 crashed into a crowd of spectators, airshow organisers in Europe and the USA were concerned that the negative publicity would adversely affect the future of airshows. Both Farnborough (UK) and Oshkosh (USA) were running concurrently. Typical reaction from show organisers was that the "media is going to fry us over this" and "those reporters won't get the story right. They never do." "This won't do anything but hurt aviation." All this angst was over the terrible tragedy in the Ukraine. It was a tragedy.

John Cudahy, President of the International Council of Airshows, huddled first with EAA officials, gasping over the graphic pictures that had just crossed the wires. They clearly showed the Russian-made interceptor fatally low, wing-down, angling for the spectator enclosure. Successive frames showed the wing hitting the ground, then the horrible somersault and fireball that inevitably followed. They shook their heads with the realization that the media would soon be heading their way, asking tough questions about airshow safety. It was clear the leadership of these two organizations believed they had to do something. The question was, what to do?

"I guess we should hold a news conference," said Cudahy. "What should we say?" asked an ICAS public relations specialist. "Keep it general. Don't give them a chance to nail you," was the advice from one 'stunt pilot'. The leaders of ICAS and the EAA were in hunker-down mode, ready to fend off bloodthirsty reporters who wanted to crucify general aviation as a whole and the Oshkosh show in particular.

As tragic as the Ukraine crash was, it presented both organizations with a chance to prove that the American way of conducting airshows was the safest, most entertaining way in the world. That's no accident, it's the result of hard lessons, high standards and good planning. Nevertheless, not everyone sees it that way. Some wanted to hold a news conference, while others wanted to wait for the media to come to Oshkosh. Still others wanted to deal with the issue by handing out a generic news release. ICAS President John Cudahy's views were grief at the loss of innocent lives. "Could it happen here?" "No," Cudahy said definitively.

Why not? Similar to the regulations in force in the UK the following were listed as the reasons militating against such an accident in the USA. "Firstly, no aircraft performing aerobatics is allowed to fly in such a way that points its energy at the crowd. Secondly, no aerobatics are performed within 1,500 feet of the line holding spectators back. That way, if there's a mechanical problem or a personnel issue on board the aircraft, no debris will reach the crowd. Thirdly, every acrobatic pilot at every airshow has to go through rigorous training before being allowed to perform at an airshow. They have to be competent and they have to prove it."

There have been disasters at American airshows, but none of them have resulted in spectator fatalities in more than fifty years which bears strong testimony to the quality of American airshow standards and certainly tells a positive, reassuring story to the millions of people who, over and over, will watch the video of that crash in the future. Fifty years is a long, long time to go without a spectator fatality.

So, how does one deal with the media after an airshow accident? There are obviously several guidelines that have evolved over the years. Firstly, don't be afraid to tell the story and secondly, don't be afraid to answer the tough questions. Reporters can indeed be like sharks in the water when they smell fear, but if you stand up and tell the truth, you'll be understood, vindicated or appreciated, depending on the circumstances. The sooner airshow organizers realize this, the sooner they'll enjoy heartily improved relations with the media. They'll be more able to get their message out instead of reacting negatively to tragedies like the recent crash in the Ukraine.

The worst-case scenario obviously is a mud-slinging denial between the relevant parties trying to duck issues that could implicate them in negligence with the consequent ramifications of legislation and possible jail sentences. In an article published in the Russian media on 15 August 2002, headlines claimed: "Lvov Mayor Blames Journalists for the Tragic Airshow". The Lvov newspapers *Express, Visoky Zamok* and *Postup* accused the city government of lies concerning the degree of their participation in the organization of the tragic airshow in Lvov. They wrote that the mayor had lied to the citizens of Lvov. The mayor of Lvov, Lubomyr Bunyak had stated in a television interview that he did not know that the airshow was taking place on 27 July 2002 and he had nothing to do with its organization.

Several newspapers subsequently published copies of documents, which cast doubts on that statement. They demanded that the mayor should publicly apologize. In return, the mayor accused journalists of attracting people to the disastrous show and stressed that he did not sign any papers regarding the show. The press service of the municipal council of Lvov wrote in its statement that the newspapers published notes and advertisements for the coming airshow, inviting everyone to attend. Lubomyr Bunyak said: "I would like to know, why they didn't confess, who rendered the precise information regarding the programme of the show, who advertised it, and finally, who paid for those publications?" The mayor also claimed that it was the journalists that had to apologize "for their criminal agitation." He also advised them "to pray at church."

In the meantime, journalist Bogdan Kufryk from the newspaper *Express* , sued Lubomyr Bunyak, claiming that the mayor illegally made him leave the pressroom at the briefing on 7 August 2002. The reason for such an action was explained in the following way: "Your newspaper was not invited for the briefing". The journalist perceived that as revenge to his recent critical articles.

There is of course another angle to the media, uninformed show organisers and advertisers, without realising it, in their search for sensationalism, often do the airshow circuit a great injustice by referring to airshow pilots as 'daredevils' or 'crazy stunt pilots'. Feeding the frenzy of 'adrenaline junkies' that go to airshows to feed their need for excitement, worst of all, creating the impression that the airshows are without regulation and a free for all, 'come for a wild ride'.

In the main, the media, newspapers, TV, radio, etc, seem to be totally uninformed about aviation in general and airshows in particular. Sensationalism is seemingly the only focus while often using inaccurate reporting and dramatic terminology in an attempt to attract the attention of the masses. There are many examples of inaccuracy but the one that beats most is that referring to a Harvard forced landing in South Africa following the AAD airshow in September 2002 in which the media reported that the two pilots had ejected safely from the Harvard. The media not realising that the Harvard, a vintage trainer, has never, and would never be fitted with ejection seats, didn't seem to realise the adverse impact on their credibility. Credibility is earned through investigative journalism that confirms the facts and not necessarily the sensationalism of the 'scoop'.

A bad media in any business can prove disastrous and in many cases essential safety of flight information is possibly withheld as organisers and managers scramble to avoid accepting any form of responsibility. The worst effect, however, is the negative publicity for aviation in general and airshows in particular.

ANTI-AIRSHOW LOBBY

For all the demonstrated support for airshows worldwide, the public, especially those living in close proximity to the airfields, generally understand the hazards and threats posed by airshows. Irrespective of the fact that they knowingly purchased their homes near to an active airfield, the anti-airshow lobby, consisting of aviation and non-aviation enthusiasts alike, has serious misgivings about airshows. There is an anti-airshow lobby and in the minority they may be, but they do however, exist. History is resplendent in examples of the achievements of dynamic and vociferous minorities that have often swung an argument in their favour, even in the face of huge majorities. The threat imposed to airshows by anti-airshow lobbies, must not be under estimated.

One of the particular gripes according to a member of such a lobby is that "military aircraft are inherently dangerous to be around, I suppose you could say the same for stunt aircraft. Having been around them as I have been, I really have to question the sanity of airshows. There isn't a year that goes by where there aren't casualties involved. Pretty senseless since they never had to happen in the first place. Had those two guys in the Tomcat that crashed at Willow Grove, USA in 2000 during the wave-off manoeuvre been doing their thing out over the water or over relatively uninhabited areas at higher altitudes, like they usually are, they could have ejected and lived as opposed to killing themselves so that innocent civilians could be spared. Airshows suck".

"I am surprised that they still allow airshows. Sure, there may be fewer incidents, injuries and fatalities from those than from other entertainment forms, but considering the strict regulations for air traffic and the safety considerations, it is a wonder that they have not been abolished. The last airshow I watched was at the Friendship Festival in Fort Erie a few years ago; there was a crash at that one. Aside from the loss of human life in some of these crashes, sometimes even spectators, there is incredible financial loss. It's hard to understand an air force risking the loss of multi-million dollar aircraft to entertain a crowd".

Commenting on the F-14 accident at Willow Grove, a senior analyst of the Center for Defense Information in the United States, said his group had confidence that the military worked to minimize the risks involved with an airshow. However, the group questioned the monetary cost of the performances and whether taxpayers should foot the bill for the entertainment. "At a certain level they are no longer recruitment tools, the whole idea is the military loves great public relations," he said.

In particular, he attacked the media and celebrity flights that often preceded such events, calling them an unfair opportunity and a waste of funds and said that a good compromise might be more static displays and fewer performances, offering access to the military bases, but not overspending to attract people. Still, the group realized that such a sentiment would not be popular with airshow regulars. “Locals would rather see the fly-bys,” he said, “and unfortunately, I end up paying for it.”

A Warrington (USA) resident and spectator at the ‘Sounds of Freedom’ airshow who served as a survival equipment specialist in the Navy for twenty years, said he thinks events like the ‘Sounds of Freedom’ show contradicts the normal safety procedures of the military. “When the planes are banking around, these guys don’t stay over the base,” he said. “We’re just lucky the F-14 didn’t crash into a built-up area.” Under normal operational conditions, the base identifies potential accident zones and prohibits flight patterns above certain residential areas. However, for the airshow, the FAA grants waivers, bending some of those rules to protect the large crowds on the base. He also suggested that performers should be banned from their own hometowns, for everyone’s safety. “They’ll usually have local guys as the pilots, and so they’re going to push it a little more to impress their family and friends”. One last counter thought though, criticizing the pilots is unfair, the display pilots in most cases are not a bunch of ‘stunters’, they are trained, skilled aviators.

Following the crash of the four-engined Royal Air Force Nimrod into Lake Ontario, the silent disbelief paralysed the more than 100,000 spectators crowded along the shoreline attending the Canadian National Exhibition in September 1995. Comment from an observer on the day: “While I love to see military demonstrations at airshows, I can’t help but wonder why the command that sends the aircraft doesn’t sit the crew down and have a long hard talk about showboating. After all, a B-52 is NOT an F-16, and you do not need not prove it to the crowd. The Nimrod show basically consisted of lots of steep turns at extremely low altitude, followed by radically nose-high climbs”.

Helicopters raced to the site about two kilometres from the shore, and divers reached the wreckage of the plane lying in about 20 metres of water, shortly after the crash. The search was called off when darkness fell and there were no reports of survivors. Shivering witnesses wiped tears from their eyes late Saturday as they sat staring out at the blackened waters. “It makes me sick, I can’t believe it,” said one spectator, “I haven’t been able to stop shaking.” The three-day airshow was put on hold after the crash, the eighth accident in the Canadian International Airshow’s 46-year history, and some were calling for an end to the show. “I don’t feel like the entertainment value of the airshow is worth dying for,” said another distraught spectator.

Following the Ukrainian Su-27 Flanker airshow accident on 27 July 2002, CNN launched a survey in which it quizzed 56,335 respondents with the question “Is it time for a ban on public airshows?” 70% (39,430) responded NO, while a significant 30% (16,905), responded YES! It is interesting that there had been a lot a baying the cancellation of airshows by the public following recent airshow accidents, but however callous it may sound, the ratio of the relatively few number of people killed versus the millions of people that have attended airshows over the years, is small. If one considers how many times football stands have collapsed killing or maiming many fans; the Ellis Park Rugby stand collapse in South Africa and the Hillsborough soccer disaster in the UK are two examples in question. So why were there no calls for football to be banned? Surely the most logical course of action would rather be to take steps to improve the situation through education, regulation, safety standards and skills upgrading.

In August 2002, the organisers of the long standing Biggin Hill Air Fair eventually decided to also call it a day, not because of accident rates, although their recent run of bad luck is a sadness, but because of the high cost of the required police presence and the security burden. By late December 2002, the decision was changed again; the Biggin Hill International Air Fair had been saved by *News Shopper* newspaper after months of negotiation between the newspaper, Air Fair organisers and business chiefs. The newspaper became involved when it was revealed that 2003 event would have to be axed because of escalating costs. With £100,000 needed to guarantee that the event would be held, was a tough task, but *News Shopper* came to the rescue.

Publisher Martyn Willis, who led the negotiations, said: “I am absolutely delighted we have been able to step in at the eleventh hour and save the Air Fair. This airshow and its links with historic Biggin Hill are famous around the world and it would have been terrible if it had folded”. Jock Maitland, of Air Displays International, which organised the annual event, said that it was vital that the show was saved since it filled an important date in the UK air display calendar. He said: "I am very pleased and relieved that this historic display is to go ahead".

In the ongoing onslaught against airshows, the combined impact of 11 September and the relatively poor international airshow safety record, the next victim to fall was the biggest airshow in Russia, both a marketplace for arms sales and a chance for aviation enthusiasts to see the best of Eastern European aviation. Just a little more than two weeks after the Su-27 crashed into the crowd of spectators at an airshow in the Ukraine, military aerobatics at Moscow's Civil Aviation Airshow were abruptly cancelled on 15 August 2002. The Russian formation aerobatic team and Italian Air Force's *Frecce Tricolori* formation aerobatic team were supposed to have performed during the 'Open Sky' section of the airshow. Instead, 'Open Sky' featured static displays and a demonstration by the Russian Emergency Situations Ministry on fire-fighting and rescue operations. The *Moscow Times* quotes Alexander Neradko, head of the Russian Civil Aviation Service as saying, "We cannot ignore the Lviv disaster."

Even though the aircraft itself hadn't officially been faulted in the Lviv tragedy at that stage of the accident investigation, Russian CAS Neradko told the *Moscow Times* : "The signals we are getting do not give us grounds to use these aircraft in demonstration flights." Sergei Rudakov, the general director of the Domodedovo Airport where the week-long airshow was taking place, expected fewer people to attend because of the cancellations. Still, he said, "as many as 80,000 spectators will show up on Saturday and Sunday".

REGULATORY AUTHORITIES

It is clear from the foregoing that the dynamics of low level manoeuvring poses a hazard not only to the display pilot, but also the spectator and even the non-spectator member of the general public who just happens to be in the vicinity of an airshow. The commercial drive by organisers to make money for their respective causes on the one hand, and the pilot's desire to provide a scintillating airshow on the other, is a contradiction in terms of safety. In this specific contradiction, airshow safety stands the risk of becoming the 'sacrificial lamb'. It is therefore necessary, as are most things in life, for some form of regulation to protect all parties involved, in particular, the pilots, the organisers, the spectators, the general public and of course, public and private property. Within today's regulatory society, the show organisers are increasingly being held accountable, health and safety regulators have to enforce 'best practice' in an effort to avoid litigation from airshow injuries and accidents.

Unfortunately, there are bound to be some unscrupulous show organisers but there are also some pilots out there for which regulations bring out the worst in their personalities. The one type of pilot that airshow organisers cannot afford is the 'Prima Donna'. Often the old hand that has been flying the airshow circuit long before the regulatory authorities were even in place – knows not only all the answers, but also all the questions. Doing it 'my way', there is nothing that anyone can tell him about the aircraft or how to fly displays because accidents only happen to others. Not understanding that the regulations are primarily imposed to improve the safety margins for spectators, the sole driver in this case is the ego and no amount of reasoning is accepted. The mindset is 'juvenile', "its my aircraft, I paid for it, I rebuilt it and I will fly it at whatever speed and height I like – if you don't like it, I'll take my aircraft home and will not fly in your show"! Yes, this did actually happen.

Worst-case experiences for show organisers and to quote one in South Africa: "We promulgate stringent crowd control and safety measures to ensure that no member of the crowd can get injured even if a pilot 'cocks-up', but we get lots of resistance from the 'show must go on attitude' of both the organisers and pilots. Its amazing how quick organisers back down when their most spectacular display aircraft threatens to withdraw if the pilot doesn't get his way. Ninety-nine percent of the time, however, if you can call their bluff, they will back down, alternatively, the aircraft's sponsors can be solicited to assist in enforcing the regulations and to 'settle' any disputes that may exist."

"The initial briefing to pilots must be such that there is no doubt as to the requirements of the airshow, in fact, preferably even before the pilots arrive at the airfield. In the past there have been recorded instances at a number of airshows throughout South Africa where pilots attended the formal briefings and received prior conditions for airshow participation, but yet still 'misbehaved'. These pilots are often professional pilots who when invited to the smaller airshows where the organisation is somewhat lacking in stringent control, arrive overhead the airfield inverted in line astern at 30 to 40 ft agl, to announce their arrival (where would number two go in the event of an engine failure?). They then proceed to tell the organisers how they will conduct their flights, which are often way below accepted minimum standards".

How low is low enough? How low before the pilot vindicates his ego? And then the question of angle of attack versus pitch attitude. How much preparation went into planning this part of the sequence? How far does the Airshow Safety Director let the pilots go before reining them in? Lucky? (Air Zimbabwe Boeing 707 flypast at Charles Prince Airport, Harare, on Sunday, May 9, 1993, during the Mashonaland Flying Club's Air Day'93. (John Miller)

"The airshow organisers are only too happy to have them there and therefore accept anything that will attract more of the paying public since the airshow is organised on a shoe-string budget. These types of pilots test the airshow organisers every time they arrive and will expect a rebuke of some sorts and live with it. If a rebuke is however, not given, they continue to fly at their own whim, much to spectator delight of course, but definitely not in the best interests of airshow safety".

"Then there are those airshows which just have no clue about safety. Allowing cars to park on both thresholds, 'first come, first served' – a crowd-line 20 metres from the active runway, where flypasts are conducted from 6 feet to 100 feet. Each participant trying to out do the next. Although the CAA was present, at no time did they intervene. This silent observation, merely gave the airshow organisers and participating pilots the go-ahead to continue as they please. Criticism raised after the show regarding the poor safety regulation imposition was met with the standard retort: "but the CAA was here and they said nothing, so what are you on about?"

Comment from another airshow organiser in South Africa: "I sent the Sea Fury away on a display at AFB Swartkops because the pilot refused to conform with SAAF show regulations and limitations, his sponsors soon put him in his place though and he eventually complied with the show specifications". Considering "Man's" excessively large contribution of 78% to airshow accidents, the arrogant attitude toward safety regulations is difficult to understand. There is a significant difference between arrogant ego and a healthy display aggressiveness – the first one can most certainly kill you, the second one can produce an aesthetically appealing display.

Unprofessional display pilot habits are a universal phenomenon. In another scenario sketched by one of the largest international airshow Flight Display Officers, is the frustration of working with certain pilots. "There is no doubt in my mind, although of course it is a wild generalisation, that the greatest difficulties I have experienced in supervising air displays is the so called 'professional pilot' flying a puddle jumper or warbird at the weekend. Put the combination of a 747-400 captain in a 'historic' at the weekend and you can have all the wrong combinations. Inappropriate experience, status which is faulted, operational support which is not there, documentation a real shambles because that's someone else's job and no one to make the coffee - sometimes, a real pain".

This phenomenon is not only found in the smaller countries where a few pilots have the monopoly in the local airshow circuit and in terms of their overall experience, are able to overwhelm the regulatory authorities and dictate the limits of the show boundaries. However unprofessional it may be, they become a law unto themselves. It is precisely because of such elements that regulatory authorities with legislative powers must exist if display flying and airshows are going to continue to remain safe venues for the pilots, spectators and the public.

Although airshow and flight display accidents occur occasionally the world over, there is no formal international body equivalent to the International Civil Aviation Organisation (ICAO) or any other similar authority that exercises international jurisdiction over airshows and addresses airshow accidents and safety issues in particular. In most countries, general aviation airshows and display flying are all controlled by their respective Federal or Civil Aviation Authority (CAA), General Aviation Safety Council (GASC), or some other regulatory body, except in Europe and the United States. In European context, the European Airshow Council (EAC) was established to promote excellence and safety for airshows within Europe. The International Council of Airshows (ICAS) exists in the United States and addresses regulatory issues, but only within the USA and Canada. Both EAC and ICAS each have an annual convention that has as its purpose, the sharing of safety and knowledge.

Within the realm of flight test demonstrations and airshows and considering the frequency of accidents and the non-existence of a universal regulatory body, the Society of Experimental Test Pilots (SETP) in the USA concluded that a vast of amount of airshow experience resided within the test pilot fraternity. Since there was no single forum collating the vast amount of airshow experience, the Airshow Safety Committee was established to research airshow experience with the purpose of providing a database from which other airshow performers could learn the lessons of the past masters. Sadly, this forum was abandoned. However, anything that the SETP used to have in the way of an Airshow Safety Committee, while not a regulatory body such as ICAS, was more safety and procedural in nature.

In the USA, the Aerobatic Competency Evaluation (ACE) programme administered by ICAS, provides the entire airshow industry with a tool for periodically evaluating the aerobatic competence of airshow pilots. ACE's main objective is to establish industry standards for airshow pilots who perform in the USA and Canada. In a rare partnership between ICAS, Transport Canada and the FAA, the ACE programme prescribes minimum standards, the rules and regulations by which evaluations are conducted, and the necessary qualifications for both evaluators and airshow pilots.

ICAS developed the 'Aerobatic Competency Evaluation Program' (ACE), similar to a Display Authorisation in the UK, which allows different levels of minimum flight altitude that can be achieved through experience and evaluation. Since 1991, ICAS has administered the programme on behalf of the U.S. FAA and Transport Canada. The organisation maintains the paperwork and a database and as an indirect result of ICAS efforts, there has been zero spectator fatalities since 1952 while there has been a 68% reduction in airshow accidents since 1990.

In earlier years in the USA, the FAA authorized the local Flight Standards District Offices (FSDO) to watch a practice and as long as the display pilot did not flagrantly break any rules, the Aerobatic Competency card was issued. However, in 1998, the FAA handed over the 'regulatory' side of qualifications to the International Council of Airshows, Inc (ICAS). The ICAS ACE program is real and is intensive in its requirements for both initial qualification and recurrency. What is interesting is that in order to get a US Department of Transportation FAA Statement of Aerobatic Competency card, it has to be approved through ICAS, a corporation?

The scale and diversity of airshows throughout Europe is vast, from the largest military airshow in the world, the Royal International Air Tattoo in the UK, to the rural airfields in France and Belgium, organisers, performers and aviation authorities need to adapt to best practice, ensuring that every eventuality is assessed to improve airshow quality and safety. During 2001, workgroups were established to set common European standards and identify ways of standardising safety regulations across Europe.

The British CAAs response to a spate of four accidents in the 1996 UK airshow season, three fatal and one non-fatal, led to the establishment of a Review Group to analyse all display related accidents and to make recommendations to prevent a recurrence of such accidents.

Recommendations were made addressing the total spectrum of display activities, including the Display Authority Evaluators (DAE) responsibilities, display pilot's practice and currency requirements, including a requirement to demonstrate spin recovery knowledge and practice when renewing the DA. Formation flying requirements, specifically those dealing with leadership, were completely revised. Finally, Display Organisers guidance and regulations, particularly with reference to the use of Flying Control Committees, were implemented and a recommendation was made that the Flying Display Director should not take part in the flying programme during major events.

Within the UK specifically, two organisations are responsible for the conduct of flying displays, the Ministry of Defence (MOD) for those displays held at military venues or where all the participants are military, and the Civil Aviation Authority (CAA) for all other displays. There are no significant differences in policy and regulation and the common denominator is 'public safety'. The civil requirements have a legal basis in Article 70 of the Air Navigation Order (ANO) which requires the Show Organiser or Display Director to obtain permission from the CAA to host an airshow. The pilot of the display aircraft in turn, must ensure that the Organiser has authority while the Organiser must in turn, ensure that the display pilot is the holder of an appropriate CAA-issued, Display Authorisation.

These legal requirements are translated into practical guidance in a Civil Air Publication, CAP 403, the "Flying Displays and Special Events: A Guide to Safety and Administrative Arrangements". Having first been published in 1973, the ninth edition was published in 2002. The CAP provides the airshow organisers and display pilots with a standardised framework to comply with the requirements of the ANO, addressing issues of legal impediment, preliminary planning, site management, CAA policies, pilot display competency and much more. Finally, each airshow is monitored by the CAA through a Flying Control Committee consisting of experienced display pilots. This committee is independent of the Organising Committee and is authorised to censure a pilot, curtail a display or, as a last resort, to stop either an individual or the entire display.

Display pilots are required to pass an initial evaluation to gain a Display Authorisation (DA) and need to revalidate their DA every twelve months. The CAA appointed a team of approximately fifty highly-experienced DAEs whose primary purpose is to monitor airshow safety, ensure regular communication between Display Pilots and the CAA and host an annual pre- and post-season seminar where safety matters and the season's activities are discussed. This mechanism obviously also serves as the platform for continuously monitoring the need for change.

It is important that display pilots understand the logic underpinning the regulations, the need to adhere to them and to have a positive approach to safety. The message propagated by the CAA is that safety takes priority over all aspects of the display. To quote from the CAA Display Newsletter: "A positive approach to display currency, adequate practice in general and on type, and probably the most important, a significantly increased awareness of the need for, and the benefits of, supervision and oversight. Furthermore, as display pilots, we must be comfortable both with receiving and with giving constructive criticism, its pretty useless, after an accident, to say: "I always thought he would do that, after the event".

Facing the challenges posed by the rising costs, security threats and the requirement to attract crowds to airshows in Europe, at the European Airshow Council (EAC) Convention 2003 held in Hasselt, Belgium in February 2003, the title theme for the annual convention was "Bringing Europe Together – by sharing experience to face the future". The future of airshows in Europe, commonality of airshow regulations, safety standards, plus the ever-rising costs of staging airshows were the dominant themes. The convention brought together more than eighty delegates from the airshow industry, comprising organisers, performers and aircraft operators, plus military and civil safety experts – the largest convention delegation yet in the EAC's history.

In particular, the first-time presence of a delegate from Russia was welcomed as evidence that the EAC was, at last, successfully forging links with airshow industry representatives in the CIS and Russian Federation countries. Performers from Jordan who made the trip to the convention also demonstrated the desire of Middle Eastern display pilots to achieve common understanding between themselves and their counterparts in Europe, especially as an increasing number of Arabic and North African national display teams now appear each year on the European airshow calendar. Special guests of the EAC from North America were the president of the International Council of Airshows, John Cudahy, and the USAF's display co-ordinator, Larry Schleser, who each gave a US perspective on airshows during the two-day convention.

It was no coincidence that the convention opened and closed by questioning the future of airshows in Europe. Using aviation magazines as a source of reference, EAC vice-chairman Paul Bowen claimed that UK airshows had declined in numbers by nearly one-third since 1990 (his figures excluded rallies, aerobatic competitions, garden fetes and small-scale local aero club events). The dramatically rising costs of staging airshows were, Bowen claimed, largely the cause of the decline. "We're in a costs spiral and, if we don't act, the costs are going to beat us", he forthrightly told the convention in his keynote address on the first day. "We've got to acknowledge that the costs are going up, so the price of attending is going to have to go up. We have to ask ourselves: What is the maximum we can charge?"

No one present questioned Bowen's assertion that the costs of staging airshows are in danger of spiralling out of control. As in Canada, insurance premiums, in particular post-9/11, were among the biggest contributors to an airshow organiser's financial headache in 2003. Businessman Alan Smith, who was also a non-executive director of the Royal International Air Tattoo (RIAT), told delegates: "Insurance companies have taken advantage of what has happened within the past few years, to greatly increase their premiums". Charges made to airshow organisers by European Ministries of Defence, police forces and by other organisations which, in more liberal times, had their manpower and financial resources absorbed by central government, were all now progressively being passed on to the public as they enter the airfield gate. The most searching issue for the EAC delegates was how to meet these cost challenges without pricing airshows out of the public entertainment business.

Ray Thilthorpe, Display Director for sea front airshows staged at Southend, Essex, and Southport, Lancashire, believed that organisers had to be realistic: "If it is necessary to pay the market price to stage an airshow, then organisers have to charge the market price to the public", he asserted. In addition, payments made to the owners and operators of historic aircraft are currently not adequate for them to meet their running costs, stated Rod Dean, Head of the UK Civil Aviation Authority (CAA)'s General Aviation Department. "Pilots want to be paid a realistic amount for their aircraft", he told the convention. EAC delegates in Hasselt acknowledged that performers and owners of historic machines did the best they could to defray the costs of their displays to airshow organisers. Dean asked the Convention how EAC members could combat 'unrealistic' hikes in premiums being forced onto event organisers. He reminded the audience that even some of the Queen's Golden Jubilee events in 2002 fell by the wayside because they could not meet the huge insurance premiums being demanded of them. It was not, therefore, a problem unique to the airshow industry.

From a performer's perspective Jacques Bothelin, director and leader of the *Khalifa* Jet Team, felt that the airshow industry benefited from having very professional pilots who risked their lives, for what by comparison with other forms of high-energy technology entertainment, was very little money. "The closest we are, is to being like a circus", he told the convention. "It is like paying ten Euros to watch a trapeze artist perform. I don't think Formula 1 racing drivers would risk their lives for ten Euros!" When asked what the public would get for their money if they were asked to pay more at the gate for airshows, he was emphatic in his reply: "Emotion! An airshow should be a whole entertainment, with special emotion – like you would get if you go to the theatre, or see a good music performance, or even going out for a good meal at a nice restaurant".

"The public will not pay just to watch you fly any more", he reminded his fellow display performers in the EAC audience. "There are so many opportunities for people in France and the UK to see major display teams that it is no longer exceptional for them any more. Instead, you must think about the emotion you bring to a display, to make it special – not just think about the technical performance". Mike Brennan, CEO of Main Event Catering, one of the most experienced companies in providing expertise and support to outdoor event organisers, was unequivocal in his advice to the convention: "Put the ticket price up with pride!", he told them. "People will spend more if we give them a 100% experience". It was important, he emphasized, to find a happy medium, to balance the overall cost of airshows with the right price for an entrance ticket. The cost to the organiser lay in improved airshow infrastructure, including good quality catering, WC and security facilities, all of which are vital for an outdoor event to succeed, whether it be Formula 1, a major sports occasion, or a rock festival.

In addition, Brennan had good news for aviation enthusiasts when he reminded the convention: “It’s not a bad thing to have airshows run by enthusiasts for enthusiasts, providing the product is good enough”. For Brennan, the flying display was pivotal and organisers needed to pay special attention to the content they put on show – which meant, not just fast jets, but an entertaining mix of aircraft types and airshow acts.

The variations in flight safety rules between different European nations, particularly in relation to display height minima, were also of major concern to delegates. Dean asserted that the UK had in place a mature set of rules and regulations, which were still being revised, but, in his opinion, did not require radical change. But, is the application of the rules consistent? he asked. Flying Control Committees (FCCs) are not mandated in the UK, but the CAA’s Safety Regulations Group strongly recommends their use. “It is the smaller shows which give us the most area of concern”, said Dean during his presentation, “because there is usually no one to monitor their operation”. He also focussed on the increasing problem in the UK of police and Health & Safety services impinging on the aviation authorities’ areas of responsibilities, which had created some local problems for airshow organisers.

Feedback from group discussions highlighted the need for commonality between military and civil safety regulations, ideally agreed within the JAA. There was a role for the EAC in promoting the airshow industry’s concerns over the lack of safety standardisation. “We need to go back to our own MODs and highlight the weaknesses”, former Red Arrows team manager Les Garside-Beattie told the convention, having chaired a group discussion on civil and military authorities. “The EAC has a role in promoting safety training courses”, he claimed, especially through a document that would act as a voice from experts within the airshow industry; plus there could be more symposiums to aid the transfer of experience. Gilbert Buekenberghs, EAC chairman, reported on his event organisers’ group discussion by saying that there was real value in organisers sharing experiences on the Internet. His group raised the question of holding forums throughout the year, to follow-up subjects featured in the convention.

Jacques Bothelin, reporting back on airshow participants, said that his group felt there was a lack of co-ordination between the dates of major airshows within Europe: “There needs to be dialogue between the big military shows to spread their dates throughout the season”, he emphasized. He also said his group were concerned as to who, how and when should anyone intervene with a “pilot who is not safe”. Is it the Flight Safety Committee’s task, or the other airshow pilots’ responsibility to do this?” Bothelin’s group also highlighted how important for flight safety the need is for comfortable overnight accommodation for airshow pilots – a bad night’s sleep before a display can adversely affect performance and, consequently, safety. But, while the costs and safety issues were the main focus for the convention, delegates were also treated to a very wide-ranging selection of presentations from individuals and organizations that contributed to Europe’s diverse airshow industry.

Graham Hurley and Sean Maffett, TV producer and airshow commentator respectively, presented the ‘Theatre of the Air’ concept which was pioneered by the RIAT at Fairford. The use of big screens, scripted scenarios involving trained actors and pre-rehearsed demo pilots, including especially stage-managed set-pieces to create airshow theatricals was mooted. Gilbert Buekenberghs complemented this presentation by describing how the Sanicole International Airshow in Belgium, of which he was the director, blended airshow acts with pop concerts and big screen live entertainment. “Spectators demanded a good variety of entertainment at an airshow”, Buekenberghs reminded the convention, “talk shows, music, promotional acts, interviews with the pilots, clowns, artists – all can make an airshow lively and enjoyable, as well as providing entertainment for the early arrivals and the late departures”. “Attract people who have never been to airshows”, Buekenberghs enthused, and especially bring in more young people who may make future careers in aviation.

Linked to this presentation, Jean-Louis Monnet, CEO of the FAI’s World Grand Prix event, described how successful the concept of an ‘Air Musical’ had proved to be in China and Japan. An ‘Air Musical’ typically involved fifteen airshow performers flying choreographed displays, exactly in tune with especially composed music, to tell a story in the air. A seated audience within a defined area was needed for such a show, otherwise it would be difficult to maintain their attention, Monnet espoused. Finding such locations was more difficult in Europe than in the Far East, but he believed there was real potential for this new form of aerial entertainment.

The use of IT in the airshow industry was featured in three presentations. Martin Schoonderbeek of ADS-Solution demonstrated how a software package can aid the administrative process of an international airshow, from the outset when participating aircraft are being invited, to their final departure after the show – this system had already been used successfully by the Royal Netherlands Air Force for its annual Open Day's organization. Jurgen Freytag, ground operations director for the ILA Berlin exhibition, described how IT and good communications equipment can assist the planning and manoeuvring of display aircraft on static and dispersal sites at airshows. ILA is unique, in that it used a completely portable modular airshow operations suite, set up in the centre of the spectator line, from which all aspects of the airshow were controlled except for ATC, which was managed by Schonefeld Airport's tower opposite the exhibition area. Display directors of demonstration flights have direct communications contact with demo pilots from within the ILA operations suite, which also hosts the airshow commentators and SAR/EMS controllers.

Carl Hall, director of GAN Media Group, described how to promote airshow organisers and performers on the Internet, through video streaming and DVDs, to sell events via websites to sponsors, guests and the public. GAN Media Group had created an on-line club for airshows and enthusiasts entitled WorldAviationClub, which marketed airshow DVDs – the Malta International Airshow 2002 DVD was available at the convention to EAC delegates.

John Cudahy, president of the US-based International Council of Airshows (ICAS) for North America, was the welcome guest of the EAC in Hasselt. ICAS was formed in 1968 and currently had 950-plus members predominantly from the USA and Canada, a full-time staff of six persons, and an annual budget of $1.2 million USD. The ICAS membership included both military and civilian event organisers, plus performers, support services providers and producers – including food/drink vendors and the all-important public convenience suppliers. ICAS has taken airshows forward the North American way, said Cudahy, based on a strong foundation and a shared perspective on safety – the latter finally resulted in a harmonization of US/Canadian airshow regulations, achieved in September 2002. This meant that rules for airshow flying and operations were now virtually identical in Canada and the USA. Cudahy felt the ICAS model could be of help to the EAC in its push for European-wide harmonization.

Cudahy informed the convention that ICAS has been instrumental in helping to reduce the airshow accident rate in North America to a virtual nil statistic. Up to ten years ago there were, on average, between 10 to 12 airshow accidents per annum; now that figure has been cut to nil in 2001 and a single accident in 2002. "Underpinning this achievement are rules requiring that no aerobatic manoeuvres with energy be directed towards the spectator area, a 'sterile aerobatic area' free of all but essential personnel during aerobatic displays (which includes evacuating homes beneath the aerobatic performance area!), and the ICAS-administered ACE programme for civilian aerobatic pilots.

Cudahy told the convention that North American airshow organisers have come to feel that ticket prices for States-side shows are too low as well and, as for their EAC colleagues, sponsorship was "overwhelmingly the largest issue for US airshow performers and organisers". The "wholesome family nature of airshows", coupled with their vastly improved safety record within the past ten years, have helped to make aerial entertainment attractive to sponsors. ICAS had hired a full-time sponsorship representative, among whose tasks had been to agree a package of US military airshows to offer to prospective sponsors, a system which, as Cudahy underlined, proved the effectiveness of a strong group of organisers being able to achieve far more than individuals acting alone.

Like the EAC, its North American opposite number held its annual Convention at the outset of the airshow season. With the number of American airshows running at between 300 and 350 annually, airshows remain a 'big business. The annual ICAS Convention has been running annually since the start in 1968 and more than 1,600 delegates and 200 exhibitors are usually welcomed to the Convention; in addition, more than 50 educational sessions are organised by ICAS each year. The Convention has become a special event in the US, not only for the release of the annual airshow calendar, but also a significant trade area as well where organizers hand out most of the contracts to the participants.

The standard procedure is for the *Blue Angels* , *Thunderbirds* and *Snowbirds* to release their airshow schedules and members benefited from being able to arrange their show dates to fit in with the display schedules of the *Thunderbirds* , *Blue Angels* and *Snowbirds* representatives of whom attend each ICAS convention. ICAS was very interested in dev relationships with the EAC, Cudahy told the delegates. "There are a number of things we do which I believe we can help you with", he said, "and there are a number of things that we need to learn from you". The seeds may have been sewn in Belgium for much greater trans-US/European co-operation on airshows in the future.

There is an irreducible risk in virtually every human endeavour but the current status of display flying indicates that the risks are generally controlled from the public's point of view. The aim of all current actions must be to bring about a marked reduction in the frequency of display accidents. To quote the CAAs guide for display pilots: "The art of airshow flying is to make the easy look difficult, to make the difficult appear impossible, and to leave the impossible well alone". The lack of an internationally recognised Airshow Council catering for the airshow fraternity worldwide, is a deficiency within the display world that will continue to handicap the exchange of information and best practice and impact negatively on the safety statistics of airshows worldwide.

THE FLYING CONTROL COMMITTEE

The pressure of imposing regulations is on not only the military, but also the civilian airshows. Roger Beazley, Display Director at Farnborough International since 1990 summed up the situation prevailing in the airshow circuit in 2002. "I have to say that as Display Director at Farnborough International 2002, my immediate reaction on the completion of the thirteen days of flying was one of relief in finishing with the same number of aircraft as we started with, rather than any other feeling of achievement or self-congratulatory emotion. What is significant is the fact that over the last ten to fifteen years, the liability or onus on the flying display organisation has swung from the man in the cockpit to the organiser/supervisor".

Beazley went on to say: "This swing in liability does not seem to be recognised by many in the business with some participants of the view that what they do is their business and the organisation should get on with selling tickets and fixing the toilets. I have to say, however, that this view was never evident at Farnborough where over the years participants have largely accepted the view of the Flying Control Committee, albeit sometimes with just a little bit of reluctance."

"Building a relationship between the Flying Control (or Safety) Committee and the participants is a vital step in getting the interaction right between the organisers, the supervisors and the participants. At Farnborough, it is relatively easy since the validation, trade and public day flying goes on for almost two weeks; you therefore get to know the individual aircrew very well. You also get to know the individual display profiles so well that your team can quickly spot any subtle change from day to day. What has to be accepted of course is that towards the end of such a long event, displays really do tighten up because not only are the participants probably as well practiced as they have ever been, but they are thoroughly used to the venue and local area. Maturing a display cannot be expected to take place at the one or two day airshow".

"Turning again to that relationship between the Flying Control Committee and the participant, and certainly at the larger international airshows, I have always felt that the Flying Control Committee should be more on the side of the participant than on the side or the organisers – in a strange country with minimal support, the participant needs all the help available! Again, this is relatively easy at a large international event but not so at a small event where the organiser might be rushing about doing all manner of things and the participant might have two other shows elsewhere that same day".

"An essential tenet of building that relationship is trying to promote the concept that we are all in this together with "the joint task" being to produce a safe and convincing display for the spectators with the Committee very much helping the participant in that role. At the longer duration events such as international displays involving professional aircrew, a broad based relationship is fairly easy to build although current wisdom, including that promoted by the UK

CAA, suggests that the Safety Committees should concentrate on the display and not become involved in the individual participant's day-to-day problems. I tend to disagree with this approach since I genuinely believe that a participant's problem is by definition, a flying supervisory problem".

"I also believe that provided the display briefings are kept private with the marketing, media and other non-operational people kept outside, general debate about difficulties and mistakes occurring during the previous day's flying should be openly discussed and where mistakes were made on both sides of the organisation, these should be fully aired. Professional aircrew are essentially a fairly robust bunch that work well in a team as long as that team is constrained to the actual individuals involved and no point scoring or personal invective is entered into; good-natured 'banter' is also a very effective icebreaker. Again, the UK CAA discourages open discussion in these circumstances preferring the quiet word on the side. This I fully understand when dealing with people you do not know in circumstances which are less than fully under control; all I am saying here is that an open and free debate in private on the previous days problems involving all participants works wonders in clearing the air and starting the new day afresh.

"An important issue is to accept that air display flying regulations not only provide a safety net for the spectators, the local population and the participant, but also a set of guidelines and an environment for the Flying Control Committee to use as a supervisory framework. But what is really important is to make the flying safe rather than merely inside the regulations. I do not suggest that regulations are unsafe but more that a state of affairs can develop whereby slavish adherence to a particular regulation, might well be an unsafe option. For example, we have seen display crashes caused by the participant trying to obtain extra performance from an aircraft which is already at its maximum, when a controlled fly through a lateral limit for example, might have been the far safer approach. I have always made the point that faced with such a choice, fly safely and lets then discuss the problem over a coffee after landing".

Already severely damaged from earlier impact with an An-24 static display, the Su-27 cartwheeled into unsuspecting spectators sitting along the crowd line. (Reuters)

"In all this one does however need to be totally open and consistent and if a minor incident by a participant from a distant land is mentioned, then a similar incident generated by a premier full time aerobatic team operating on their own soil, also has to be mentioned. One also has to ensure that the Flying Control Committee speaks as one and in this regard at Farnborough, I have always been very fortunate in leading an experienced and competent team. When the Chairman stands up and has to take a firm line with either a participant or the organisation, knowing that one is supported 100% by such a team, engenders a level of conviction which in turn flows through to the participant about to fly his or her display".

To add substance to Beazley's comments, the Ukraine Air Force Su-27 accident, which killed eighty-six spectators in July 2002, resulted in the Ukraine President sacking four generals, and dismissing the Deputy Defence Minister whilst at the same time acknowledging that they did not even know the cause of the Su-27 accident. Following this accident, many 'Western' countries' so-called safety experts were very quick to claim the 'moral high ground', claiming that the probability of such an accident happening in the USA or UK was virtually nil and further suggesting that the 'ex-Eastern' bloc countries should follow the West's examples of airshow regulation enforcement. This was tempting fate, such statements have a horrible habit of coming back to bite. The point is that it doesn't matter how many restrictions are built into airshow regulations, the high momentum of an aircraft manoeuvring in a confined air space can make a mockery of the 450 metres 'safety margins' for a manoeuvring aircraft.

Comment from the USA: "The Su-27 accident in the Ukraine was an enormous tragedy and our thoughts are with the families of those killed or injured in the accident," said John Cudahy, president of the International Council of Airshows. "The FAA and Transport Canada strictly enforce regulations that keep these kinds of accidents from happening at North American airshows. According to Cudahy, those regulations have both eliminated accidents involving spectators and also dramatically reduced even those accidents involving only airshow pilots. The safety record of airshows in North America is the envy of the entire motor sports industry," said Cudahy.

In similar fashion to that in the UK, the North American programme depends on the strict enforcement of existing regulations by airshow-trained inspectors from the Federal Aviation Administration (FAA) and Transport Canada. The Federal regulator and inspectors in North America mostly enjoy a strong and mutually supportive relationship with airshow professionals in the United States and Canada although there have been some problems. The strict enforcement of existing regulations is acknowledged within the industry as a critical part of our overall safety programme."

INSURANCE THREAT

Another significant threat facing Airshows, Exhibitions and also display pilots worldwide, is the aspect of insurance. In Europe, the relatively high 2001 airshow accident rate, combined with the atrocities of 11 September 2001 in the USA, added impetus to a worldwide increase in the costs of insurance. Airshows are increasingly under siege and could be lost altogether unless urgent attention is given to the plight of show organisers and display pilots. In May 2002, some of the major airports in Canada told airshow organizers holding events at their airports that there was going to be substantially greater insurance costs associated with the use of their facilities in the future. The same pattern also emerged in the UK but the increased costs could prove prohibitive in the future for all stakeholders.

On 19 April 2002, John D. Issenman, Chairman, Ottawa International Airshow, provided a synopsis of the issues at stake: "We must act now and get the word out to our Politicians, Presidents of Chambers of Commerce, Business and Military Leaders, Charities and non-profit organizations who benefit from these shows. Canadian Airshows may cease to exist if direct, immediate intervention is not taken. It is obvious that the main role players do not understand the full negative consequences of the death of airshows. The traditional 'let's wait and hope for the best' will not cut it."

Certain Canadian airports required organizers of the proposed airshows at their locations to provide proof of insurance for general liability. The required amount was $50 million USD; these airports also required the airshows to provide coverage for War Risk (terrorism, etc.) for the full $50 million USD as well - the most coverage previously provided by any airshow in Canada was $20 million CDN. The cost of the aforementioned coverage was estimated by Insurance Technologies and Programs Inc (ITPI), to be a minimum of $70,000 per show site.

Clearly, this premium is prohibitive for any airshow organizer, ITPI and their underwriters could not understand why any event would even consider this type and amount of coverage, as neither they nor their underwriters had identified airshows at airports in Canada as an elevated or enhanced risk. They had most to gain by airshows being forced into buying additional insurance, but they didn't' think airshows needed the additional coverage. At Transport Canada, neither the event Regulator (General & Commercial Aviation) nor those responsible for insurance issues affecting the aviation industry, required the additional coverage previously mentioned. Further searching for results of any 'threat assessment' carried out to determine the level of risk presented by airshows at Canadian airports, produced nothing. Insurance brokers who sold the group policy to the effected airports, as well as a number of underwriters, indicated that nobody had ever requested or received a threat assessment to determine if any elevated level of risk existed to justify any requirement for the additional coverage.

Threat assessments were however, conducted by the Canadian Department of National Defence as well as the United States Department of Defense, specifically to identify risk associated with airshows at Canadian airports. Not only was the level of threat identified as extremely low, but also high value assets from both countries as well as from other NATO allies were authorised by their own governments to attend and participate in Canadian airshows. It appears that there really

was no issue. The premise on which the perceived need for additional insurance was based, did not exist, or was false.
These issues were discussed with the office of the deputy Prime Minister, the insurance brokers who represented the airports in question, ICAS, Transport Canada, the Department of National Defence, the Air Transport Association of Canada (ATAC), representatives of the Aerospace Industries Association and management of the first four events to be effected by such additional insurance requirements.

If the requirement for additional insurance was not immediately retracted or the coverage provided free of charge without deductible as part of the indemnification supplied by either the airports themselves or the government, the airshows would have no option but to terminate their operations and cancel all plans for their respective events in 2002. Airshows in Canada are, for the most part, non-profit events, proceeds from airshows are distributed to charities and non-profit organizations in the communities where the events are held. Airshows generate hundreds of thousands of dollars of business in the communities they serve (hotels, fuel, rental vehicles, printing, concessions, merchandising, patron visits to local restaurants, sites, security services, taxis, buses, rental equipment from tents to toilets, advertising and marketing).

Hundreds of full and part-time staff at airshows across the country would be laid off and millions of dollars of proceeds from airshows normally donated to charities and service clubs across the country, would not be made (cancer research, Lions, Kiwanis, Rotary, etc). Hundreds of thousands of dollars would be lost in each and every community where an airshow once had been. Hundreds of thousands of volunteer hours would not be provided to the airshows for which these individual and group volunteers have trained and planned, including students who required a minimum number of volunteer hours as a condition of their graduation from high school.

Major corporations across Canada who had invested in airshows as a community partner, or for branding, retail, recruiting or other opportunities, would be cut off. Aerospace companies who showcased their products at these events would be denied the opportunity to present their latest and best to the public as well as their markets. The military would be denied the chance to demonstrate to the Canadian public the type, nature and capabilities of the personnel and equipment paid for by the Canadian taxpayer. The military would be denied some of the most effective recruiting opportunities they use and the Canadian Forces *Snowbirds* could be disbanded as there would not be any events in Canada at which they could perform, effectively ending their role as a Canadian icon. Finally, and most significantly, millions of young, impressionable Canadian children and adults would be denied the chance to experience the educational, entertaining and exciting airshows that generations before them had the benefit to enjoy.

The role models presented by young servicemen and women cannot be duplicated elsewhere. How many careers in the military, aerospace and aviation industries and sciences were first sparked at an airshow. Airshows are the one event that provides children with the dreams of opportunities that become the reality of hard work, staying in school and contributing to society. They don't see this in rock stars or overpaid professional sportsmen and women.

The demise of airshows was a very real probability if airports, insurance brokers/underwriters and government did not step in to rectify this requirement based on a false premise for unjustifiable additional insurance. No one seemed to know how high premiums would go but that didn't stop some from predicting increases as much as tenfold over the previous year's rates. For the city of Toronto, there was more at stake than national pride, the three-day event traditionally attracted thousands of visitors and contributed significantly to the city's economy. There's a lot of money that comes into town on that weekend, and it would be devastating for Toronto to lose that.

The threat of increased premiums was a boondoggle by the insurance industry, according to some, there is not any substantive data that explained what the 'new' risks were. Based on universal experience, what could be expected, was that there would be more police on the airfield, more people scrutinizing people as they passed through the gates, no backpacks allowed, that kind of thing. All of this put in place as a result of 9/11, without confirmation that anyone had done a proper assessment of risks. This is exactly what happened at the first RIAT 2002, post September 11. Individual body searches on each of the approximately 280,000 people that reportedly attended the airshow, caused tailbacks in queues resulting in spectators taking hours to enter RAF Fairford. UK aviation magazines and Internet 'chatrooms' were inundated with irate spectators vowing never to return to RIAT, some even threatening to save their money and rather travel to Oshkosh.

At about the same time in Canada, the following announcement was published after serious negotiations. “Due to the recent issues regarding War & Terrorism Insurance, the financial viability of this world class event and the repercussions this has caused with sponsors, advertising, entertainment and aircrew, we regret to announce that the London Airshow & Balloon Festival will NOT be taking place in 2002. With fifty-four committees, over 1,000 volunteers and an International reputation, this is a very sad day for all of us. The long history of airshows and specifically our show, could never have seen this coming. This is a loss to all of us, including almost $5 million dollars in economic impact, more than fifty-five jobs generated and over $40,000 that is contributed to local charity!”

“Perhaps more importantly, we will not be here to leave an impact on the children who are awed by the jets, or an autograph from the *Snowbirds* , the opportunity to explore aviation and the dream of flying one of those Jets, Helicopters or Balloons. At this time, those efforts have been unsuccessful, but this work is much appreciated and we are committed to continue our efforts to resolve this matter for future airshows. We trust that sanity will prevail and the show will return in 2003”. (Tourism London and the Canadian Tourism Research Institute)

The negative impact of airshow accidents and security considerations also claimed their toll on one of the world’s oldest airshows, the annual Biggin Hill Air Fair. Jim Maitland issued the following press release to Flightline UK about the troubles one of Britain’s favourite airshows was facing. “The International Air Fair of 2002 was another significant achievement in terms of the flying display and the wide ranging ground activities. However, despite this apparent success, the Air Fair, which is the only unsubsidised event of its kind in Europe, is now facing a financial crisis.”

Maitland said: “The crisis has been precipitated by costs which have escalated on several fronts over several years but spiralled drastically in 2002. The London Ambulance Service, the RAF and, since 2002, the police, have added between them £50,000 to costs. Secondly, insurance premiums have tripled since September 11 which not only pushes up the cost of insuring the airshow, but all the individual aircraft operators have to pass on their premium increases to the organiser. Finally, the increasing rigorous standards set by Health & Safety legislation and the need for tighter airport security, have very significant cost implications”.

“Up until 2002, the Air Fair has been able to absorb these costs but the very marked increases of 2002 have brought the situation to a head. Despite its unique history, location and reputation, the financial realities of putting on a flying display have caught up with the Air Fair just as they have with every other major privately organised flying display. Virtually all the major flying displays are subsidised by the tax payer in some way, either as military events or sponsored by the authority”.

“The Air Fair is unique in being the private enterprise of a small family-run business. It is with huge regret that we have decided that we cannot justify the financial risk of continuing to stage the Biggin Hill Air Fair unless we are able to attract substantial financial backing. No one will doubt our own disappointment but that of the general public will be far greater. A significant number of people have not missed an Air Fair since the beginning in 1963 and, for the first time (barring the interval needed to fight a war), since 1922, there is the prospect that there will not be an airshow at Biggin Hill”.

The major cost drivers at the RIAT 2002 were £124,000 for insurance, £180,000 for policing, £125,000 for security and £27,000 for an MOD Licensing fee. Nearly one-half a million pounds to just set the stage for the airshow – smaller show organisers will not be able to sustain such high costs to create the airshow arena. By late December 2002, the decision to cancel Biggin Hill was rescinded, sponsorship having been provided by a local News Shopper newspaper coming to the rescue of the historic event.

In Hampton, Langley Air Force Base scaled back plans to hold a three-day show in 2002 because of the security costs, a two-day show was held instead. Elsewhere, the Navy cancelled a two-day airshow at Patuxent River Naval Air Station - Air Expo ‘02, on the Navy base in St. Mary’s County, Md., which would have included performances by the Air Force’s *Thunderbirds*. Officials at the time cited an anticipated increase in security costs. So great were those security costs that the Department of Defense almost cancelled its open house in May 2002 at Andrews Air Force Base in Maryland.

But, after being cancelled in 2001, the US Navy's largest airshow returned to the skies in 2002 over a changed landscape with hundreds of thousands of spectators expected at Oceana during the three-day show. There are no admission or parking fees.

When long-time fans talk about the Oceana airshow, they tend to use superlatives, "the best organized", "the latest hardware" and "the most action-packed - it's the only thing more exciting than auto racing," are typical praises offered by spectators and aviation enthusiasts. A former military aircraft engineer from Appleton, Wis., with his 20-year-old son attended each of the days and had this to say: "the smell of jet fuel and that sound of freedom - they keep the tanks from coming down the street. If my tax dollars go towards funding airshows, that's fine with me. You start throwing rocks at the other shows after you've been to Oceana," he said.

The air station's executive officer, said that the security forces on the base had been tripled to accommodate the airshow crowds. "Other naval installations in the region would aid the security effort," said the airshow coordinator. There had been no conversation among officials to downsize or cancel the Oceana event, which had an annual budget of $500,000 and an estimated $15 million economic impact on the region. "We have been operating at a high level of security since 1998,'' said the coordinator, "patrons, need to bring a picture identification and leave their coolers and backpacks at home - small bags would also be searched".

HELICOPTER'S AND VSTOL

Although a large majority of spectators would appear to favour the noise and speed of the fast jets at airshows, since the 1980's, helicopter technology advances have produced a platform in which high agility and manoeuvrability can be impressively demonstrated by helicopters at airshows. Looping and rolling manoeuvres have become part of their demonstration package but not without first having to overcome major aerodynamic and mechanical challenges.

The advantage that a helicopter has, especially a large helicopter, is simply that any dynamic manoeuvring or aerobatics performed by a helicopter of that size, is very impressive. In addition, the small turning radii and relatively slow airspeeds, brings the display closer to the spectator thereby increasing the aesthetic appeal of the aircraft. The first helicopter to successfully perform a loop was the lowly HUP (H-25), way back in the early 1950's. Of course that one wasn't entirely on purpose, it happened during the testing of the autostabilizer, when the aircraft experienced an uncommanded pitch-up and by the time the pilot had control over the aircraft, not necessarily command, the nose was so high that keeping the g on and pulling it through, was smarter than pushing over.

In manoeuvring flight, the helicopter has some really unique problems compared with fixed wing aircraft. The conventional helicopter cannot pull negative 'g' - so the rolls are really barrel rolls; the problems aren't only with airflow, but mechanically and structurally as well. No matter what type of rotor hub is used, the blades bend because of the differing levels of lift across the span of the blade - very little airspeed inboard, lots of airspeed outboard. If the relative wind from the forward motion is added, it gets complicated very quickly, even the so-called rigid rotor hubs rely on blade flexibility for this.

Prouty, a renowned helicopter aerodynamicist, discussing helicopter aerobatics, concluded with the question: "Can a helicopter do steady inverted flight?" His answer was - theoretically, yes, but practically, no! A rotor could produce enough negative thrust to support the helicopter's weight if it were designed with enough negative collective pitch range, but this would require a collective-control system with at least twice the normal travel. If this were not the case, the helicopter would be capable of inverted flight, which it isn't.

Many helicopters have had problems, the UH-1/AH-1 tail strikes occurring when pushing over at about 0.5g, resulting in the later Sikorsky S.55''s and H-19's having their tail booms angled downward to get it further from the main rotor. The H-43 (and HOK) used to chop its tail off with distressing regularity, it didn't use a teetering rotor, but a semi-hinged design with no flapping hinges in the hub, just lag hinges, and it used a flexible rotor (controlled by trim tabs) for flapping and pitch control. There are many other examples.

'Mast bumping' is but one of the things that can go wrong, fully articulated rotors have their own sets of problems, which was one of the reasons for changing the tail on the S.55. 'Mast bumping' is a phenomenon associated with teetering head rotor systems and the solution is to keep the aircraft under positive 'g' by effectively lowering the tailboom seems more consistent and facilitates better control authority at low speeds, when larger disk travel is necessary to generate higher rates.

Basically, all helicopters are subject to having nasty things happen to the plane (cone, actually) of the rotors when flying at anything other than 1g level hovering flight. Much of this is compensated for by all the flexing and hinging, but there are limits. It is sometimes useful to think of the fuselage and rotor as two separate systems, with the fuselage hanging from the rotor(s) at the shafts. This can be seen in shots of helicopters flying dead toward or away from the observer - the rotor cone is canted to one side due to the asymmetrical lift.

Given the physical constraints imposed by helicopter designs, several helicopters have done documented loops and rolls, beginning with the S-52 in 1949, the giant CH-53 in 1968, and the various hingeless and bearingless (rigid) rotor systems that are flying today (MBB BO-105, Westland Lynx, etc). As yet, no helicopter is officially certified or approved for aerobatics and most of those that have done aerobatics are classified as experimental or prototypes.

However, loops and rolls were performed by two German teams on MBB BO-105 during the International Helicopter Aerobatics Championship 1980 in Piotrkow Trybunalski, Poland. These teams won first and third place. The second place was awarded to the then USSR team flying a Mi-1 piston-engined helicopter. On the final day of the championships the Russians performed almost the same programme as the Germans (except for inverted aerobatics, of course) but in a much more dynamic manner which wasn't surprising considering that the piston engine's response is higher than that of the turboshaft engined helicopter. The British Lynx is capable of loops and rolls with roll rates of up to 100º/sec - the Hughes 500 is even capable of doing tailslides.

The Lynx, with its semi-rigid titanium rotor head, iscapable of high manoeuvrability that not only enables the inimitable 'Backflip' to be flown, but also to combine its agility with the graceful four-ship Gazelle formation. (Blue Eagles)

Lockheed's research into compound rigid rotor helicopters already began in the early 1960s using the XH-51. In 1966, Lockheed's design for an operational attack helicopter, the AH-56 Cheyenne, won the contract to build the US Army's Advanced Aerial Fire Support System (AAFSS). The Lockheed AH-56 Cheyenne's revolutionary rigid rotor system, which had been proven in previous development testing, was fully capable of rolls and loops. The Cheyenne had a 3,435 SHP General Electric T64-GE-16 turboshaft engine that powered a rigid 50 ft four-bladed rotor, as well as a 10 ft three-bladed pusher propeller and a four-bladed anti-torque rotor on the tail. In horizontal flight, almost the entire engine output is used to drive the propeller. The third of ten prototypes crashed on 12 March 1969 when the rotor impacted the front and rear fuselage, killing the pilot. The AH-56 was highly agile and a very capable weapon system, but development was halted in 1972, due to defence cutbacks.

The Cheyenne could fly like a fixed wing aircraft and since the rotors were absolutely rigidly mounted without bearings or hinges, it could do exceptional aerobatics. The problem with loops, Prouty pointed out, is that "at the top of the loop, where the rotor thrust is zero or at least very low, all helicopters have reduced control power in pitch and roll. Those with teetering rotors may have none at all, leading to mast bumping and for droop-stop pounding on fully articulated rotors.

Although not regarded as aerobatic aircraft as such, the British Army has quite uniquely, since the early 1970s, fielded the only helicopter formation aerobatic team in the world. Flying four Gazelles and a Lynx, the team is well known in Europe for its close formation sequences, dramatic solo and pairs manoeuvres, opposition passes and the distinctive choreography of their display. Typical manoeuvre flown include the Spread Eagle, Back Flip, Crossover-Break and Eagle Roll, which were developed by the team.

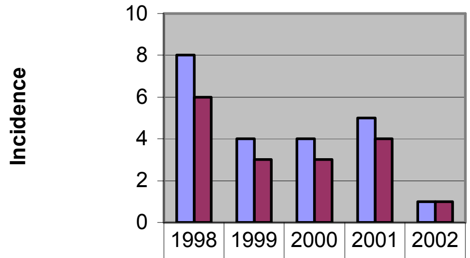
Helicopters are not excluded from the ignominy of airshow accidents. Within the analysis of 118 airshow accidents, six involved helicopters. The Sikorsky S-67 Blackhawk competitor was lost at the Farnborough Airshow 1974 in front of the crowd after 'dishing out' from the last of the two consecutive low-level rolls. A Danish Navy Westland Lynx S-170 crashed during an airshow at Goraszka Air Picnic, Warsaw, Poland in 1997, the pilot pulled out of the recovery from a wingover, too late. Fortunately, the crew sustained only minor injuries and the damage to the S-170 was not major and was subsequently capable of being overhauled and returned to service. So yes, the rotary wing industry has managed to overcome the aerodynamic challenges of helicopter flight to provide agile machines in which aerobatics are possible, but as in the fixed-wing regime, the penalties for failure are high.

TO FLY OR NOT TO FLY VINTAGE AIRCRAFT

An airshow accident is a tragic affair on its own and is usually marked by sadness, but an airshow accident by a vintage 'warbirds' adds another dimension, to the distress level. Vociferous criticism from veterans and military personnel who operated such aircraft in wartime conditions or during their military careers, usually follows. Amongst the veterans specifically, there is the strong belief that their commitment and sacrifice should not be lost to memory and it is against this background that the emotional outbursts are expressed at the loss of a vintage aircraft type.

Quite naturally, much attention is typically focussed on airshow accidents within the airshow world, and unfortunately, a large proportion of airshow accidents involve vintage 'warbirds'. The definition of vintage or historic aircraft and that similarly used by the US Experimental Aircraft Association's 'Antique' and 'Classic' definitions, is "an aircraft designed more than forty years previously"'.

In a random sample of some 118 airshow accidents between 1952 until 2002, (Chapter 3) a total of 22% of aircraft involved in airshow accidents were vintage propeller (19%) or jet (3%) aircraft. This against fighters at 29% and jet trainers at 23%, no wonder then that the aerobatic flying of vintage aircraft at airshows is such an emotive issue. Dwelling on the statistics of vintage aircraft accidents for a moment, it is instructive to consider that in the UK, according to *Flypast* magazine (March 2003), there were a total of seventeen fatal 'historics' accidents from 1998 to 2002 which accounted for a total of twenty-two fatalities in seventeen accidents, but not all at airshows.



	1998	1999	2000	2001	2002
Fatalities	8	4	4	5	1
Accidents	6	3	3	4	1

UK Fatal Accidents in Historic Aircraft (*Flypast Magazine March 2003)*

Increasingly, wealthy hobbyists, museums and aviation enthusiasts are restoring vintage aircraft and since 1985, there has been a dramatic increase in the number of vintage 'warbirds' flying at airshows worldwide while homebuilt and experimental aircraft are increasingly also entering the air-race circuit in the United States. In the UK and USA particularly, there are a large number of vintage aircraft and the loss of a specific type can normally be readily supplemented by the restoration of another, in most cases. In countries outside of the United States and the UK, however, this is not necessarily the case and vintage types may be very rare; the loss of a 'one-off' vintage aircraft can mean the loss from that museum's collection, forever.

The catastrophic engine failure of the South African Air Force Museum's only airworthy Spitfire in 2000 and the 'wheels-up' landing of the only airworthy Mustang P-51D in 2001 during airshows, serve as points in case. The cause of the Spitfire engine failure was attributed to a combination of a slipped supercharger clutch plate and a hardened carburettor diaphragm, while the mechanical failure of an undercarriage up-lock hook on the Mustang, resulted in a partial wheels-up landing, both aircraft suffering extensive structural damage – in fact, the Spitfire suffered Category 5 damage, a 'write-off'. The public outcry, particularly from ex-Servicemen, veterans and aviation enthusiasts, was damning; a vociferous call demanding that single copies of valuable aircraft not be allowed to fly. This same sentiment and argument exists in the USA and also in the UK.

Typical response from the public to similar accidents in the United States adequately amplifies these sentiments and the reaction from aviation enthusiast groups can be summarised by the statement: "I hate to be crass, airshow pilots are easy to replace but P-51 Mustangs are not! Tell me how many P-63s are left with us?" "Why do we take such chances with rare aircraft?"

The counter response from the owners of such vintage aircraft cannot really be argued against: "Because people pay their own money to restore and fly these planes, otherwise, they would not be in any condition that the public would want to see. People went in search of wrecks and planes in unflyable condition, spent lots of hours and tons of money to make them flyable. Let them fly. If you want to see a P-51 or any other type of rare warbird sitting on the ground and not flying, go to a military museum! If you want to hear and see them fly, go to an airshow. It takes even more work, and even more money to keep those planes flying." This argument is obviously valid only in the case of private individuals or groups, if however, the aircraft is restored with taxpayer's money, then the argument is strictly speaking, not valid.

SAAF Museum Spitfire Mk IX, a heartbreaking sight for WWII veterans and aviation enthusiasts, particularly those who had put hundreds of thousands of man-hours into the re-build programme. (SAAF Directorate Flying Safety)

It is evident that there are very strong views regarding whether warbirds should be flown or not. The most common call against flying the survivors from WWII is their value, which is considered too great to be risked in this way. In the UK, the decision to fly the only airworthy and fully representative Me-109G-6, is a case in point. In a discussion between two aviation enthusiasts on the subject of flying vintage aircraft: "I'll go crazy if 'Black 6' crashes before it is eventually grounded!" "Why, what good is a plane that can't fly? Just scrap metal! There are plenty of other Bf-109s that cannot fly lying around in various museums. 'Black 6' is precious because it can fly, not because it was a German warplane - I say keep her in the air".

Spectators in the UK that had had the pleasure of seeing 'Black 6' fly on many occasions, were in awe every time the sound of it's engine was heard; it was impressive, especially the supercharger whine when it came in for a low pass, described by some enthusiasts as "absolute magic!" In South Africa, there have even been occasions when spectators requested that the commentary and musical accompaniment to be silenced when the warbirds flew past so that the 'old-timers and enthusiasts' could hear the sounds of the engine of the aircraft flying past; the four Rolls-Royce Griffon engines of the Shackleton being a particular favourite.

The viewpoint of another UK airshow enthusiast: "Maybe it's a sign of increasing age, but I've grown rather weary of Duxford's presentation, which seems to have the aim of putting as many aircraft as possible into the circuit at the same time (and with backing music too, just like on TV!). It's almost a 'theme park' approach, which sure brings in the crowds for the spectacle, but I find my enjoyment and appreciation of the individual aircraft, and their personal sounds, much diminished".

Another more objective argument: "The will and enthusiasm to keep various warbirds flying is praiseworthy and most would express great delight in watching and most importantly, listening to those beautiful old warbirds. The problem is that the future generations would also like to see these aircraft, if not in the air, then on the ground. The point that is often made, is that we have a responsibility to preserve such aircraft for the next generations and no matter how experienced a pilot is, accidents can and will happen. It is not easy to understand why 'Black 6' should have been risked year after year until the final accident".

"This does not mean that warbirds should never be flown; but clearly, they are more valuable if kept in that condition and only flown on special occasions to minimize the risk and then not flown in aerobatic sequences, but rather just flypasts. 'Black 6' was a very special aircraft that could not be compared with others, it was the only flyable German-built 109, its history was well researched and it was accurately painted, few other German WWII survivors are". The sarcastic response: "So what should we do if it crashed never to be seen in the air again, show a few videos of it to our children?" Taking the argument one step further, "if you just want to 'look' at an aircraft, does its history really matter?" "You only need a highly detailed model that is not airworthy to say - hey, that's a Messerschmitt Bf 109G-6 that was used in Africa during WW2". Some warbirds are more numerous than others ie Spitfires and Mustangs, but rare ones demand special care".

"The supposed logic of flying the warbirds resulted in not one single B-26 Marauder being left in flying condition. The world's only airworthy B-26 maintained by the Confederate Air Force, which crashed outside of Odessa, Texas in September 1995, was completely destroyed and all five aboard were killed just south of the airfield while on a routine practice flight for the upcoming airshow. More importantly, pilots, aircrew and passengers died foolishly and needlessly for absolutely no good reason other than to give aviation enthusiasts a thrill at airshows. Hardly worth losing lives and rare aircraft for".

"The aircraft was flown by a very experienced pilot who hadn't flown the hazardous and tricky B-26 in four years. In order to fly an aircraft competently, one needs regular continuation training to maintain proficiency, which is nearly impossible with these 'old timers'. It makes no sense to put lives at risk just to enjoy the fabulous sights and sounds". Given the choice, the opinion generally expressed by the veterans is: "The hell with the fabulous sights and sounds, I'll take the plane instead and don't forget that a pilots life is at risk for something as trivial as the spectators amusement".

Nevertheless, getting to the crux of the problem and another side to the argument: "It's not the flying of the vintage aircraft at an airshow that has been the problem, it's 'how' the aircraft have been flown. Fly-bys are great, but why all the aerobatics? The sights and sounds are fabulous, but it is the 'tricks by slicks' that have created the problems. Adequate maintenance and properly applied piloting skills should not create any problems for a warbird, the problem is one of proficiency".

As one of many examples, the crash of the then 51-year-old DH.98 Mosquito T.3, based and maintained at British Aerospace's North Wales factory at Broughton, near Chester, is typical. The pilot and navigator were killed while displaying at a nearby airshow at Barton, Manchester, England on Sunday, 21 July 1996. The aircraft was one of only two known airworthy Mosquitoes in the world, the other being Kermit Weeks' Mosquito B.35 bomber in the USA. The emotions voiced by aviation enthusiasts all around Britain, and in particular the veterans from WW II that were weaned on the Mosquito, was quite damning.

Newscast video showed the Mosquito approaching the top of a wingover at approximately 1,000 feet agl when control was lost, the aircraft pitched nose-down then entered a spin. The pilot managed to recover, but unfortunately had insufficient height for the recovery pull-out and the aircraft crashed into a wood about one mile from the airfield in a wings-level, nose-down attitude.

The aircraft was built in 1945, having just missed war service, and was acquired by the Chester site in airworthy condition in 1963 for just £100. It had been maintained in flying condition and flown at air displays in Britain and Europe ever since. The aircraft had been totally stripped down and refurbished in 1992 for that year's flying displays and it re-appeared in its usual grey/green camouflage but with the distinctive D-day black and white stripes added. Flying hours at the time of refurbishment were only 1,746. The previous display of the 'Mossie' at North Weald was voted as the best piece of flying and not an excessive manoeuvre in sight. Maybe this is the way all these beautiful old aircraft should be flown, but, as the Manchester crash demonstrated, even when this is adhered to, any sort of problem, no matter how small, can still result in a disaster.

Comment from a veteran: "Not to get argumentative, but the question that begs asking is: "Why would someone flying a very rare, restored 50+ year old aircraft attempt aerobatics that might have been discouraged even when the aircraft was new?" "Is it the desire to please the audience, aren't they just satisfied with just seeing a fly-past of this great aircraft? Given the loss of two lives and a nearly irreplaceable vintage aircraft, should there not be some rethink on the safety issues of flying rare warbirds? However, I can comment that the 'Mossie' was generally handled with respect; typically though, the display routine included a number of climbing passes into a wingover to return at high speed along the display line. The TV video showed some quick reactions to exit the spin, so pilot incapacity was probably not a factor in this case".

Jimmy Rawnsley, navigator to the legendary Mosquito pilot John Cunningham, wrote in his memoirs that rolls were not generally recommended for 'Mossies' although the manoeuvre was considered safe in the hands of an experienced pilot. Even so, one of 85 Squadron's top pilots, Bill Maguire, was killed executing rolls while testing new Mosquitoes at RAF Ford. As part of the collective mourning over the demise of the Hatfield airfield, an ex-BAE photographic unit had put together a 70-minute video summary of the site's history in which one of the clips showed a Mosquito being rolled with one prop feathered.

The point of a wingover is that it is a gentle manoeuvre with the aircraft largely unloaded at the apex of the turn. It is essential to maintain balance as the airspeed can get quite low depending on entry speed but we are not talking low-time crew here. After this specific accident, the main thrust of a letter sent from Barry Tempest (UK CAA) to all display pilots was that while he was not pre-judging any investigation outcome, he was asking all display pilots to think carefully about their display routine and whether it had to be flown at the minimum height authorised on their display authorisation.

An interesting point of view voiced by another veteran regarding pilot skills levels and continuation training was: "The aircrew died in the crash and drove a very rare and airworthy DH Mosquito into the ground at another airshow. This is really not very surprising. After all, warbirds aren't flown enough hours to get even one pilot proficient on them. This is because they are so expensive to maintain and fuel which implies that they are often owned by organizations, which means that more than one pilot is probably flying the very few hours available, which makes matters even worse".

Worse yet, in some cases, the pilots that usually do fly the aircraft, are not necessarily the most skilled pilots but they have the right political pull within the organization. A little low-level aerobatics later, you get a hole in the ground. Now, some people do own warbirds privately but the problem is that everyone only has twenty-four hours in a day - we all have to eat and sleep, too. In some cases, someone who can afford a warbird has, in many cases, spent all his time earning money at his own business instead of flying airplanes professionally. In the particular case of the Mosquito, however, it was owned and operated by British Aerospace who imposed high standards of flight safety. The pilot was very experienced and had flown this particular aircraft many times.

In terms of cost, operating these aircraft is unbelievably expensive and the huge crowds drawn to the big displays are essential if the aircraft are to continue at all. Thus, the display must be sufficiently exciting to appeal to the non-enthusiast who has paid his money to get in and wants to be entertained. The challenge for the pilots and display director is to give the impression of great activity and excitement while actually maintaining a safe operation. The UK shows such as 'Flying Legends' and 'Fighter Meet' have done this very well for many years, without that income, not many of the warbirds would still be flying!

Additional comment on the issue: "Over the past couple of years, I have to admit leaving some airshows at the end of the day relieved when nothing had been damaged. I prefer to go to the Shuttleworth Collection at Old Warden these days. I get that reassuring feeling my admission money is contributing to the performers' conservation, not their consumption. The great wonder of this particular aircraft was that it was not a restoration, it had simply managed to survive in working order since it was built, and it was cared for by the direct descendants of those who built it. Genuine aviation enthusiasts would probably be content with the gentlest of fly-bys at low-cruise power".

It is thus obvious that aviation enthusiasts the world over are somewhat torn between the two extremes, they love to see the vintage aircraft flying as they were meant to be flown, but would also hate to see all examples of a type destroyed in crashes. The debate into flying vintage machines or not, without understanding the strict rules that are adhered to by all organisations that undertake their continued maintenance, is irrelevant. The pilots deserve better. There is a side issue challenging the future survival of the vintage rebuild market however, it is a single issue that might ground at least some ‘warbirds’ in the future and that is insurance. Even if you risk not insuring the airframe, how much will the premium be raised now? Too much for some? Most probably!

So, to fly or not to fly, that is the question. In the words of the restorer of the vintage AT-21 in the USA: “I know that when my AT-21 finally gets back into the air, it will probably not be flown at the few airshows I take it to. I want to be able to show it off, but I also want it to survive for generations to come. I say this for a couple of reasons. It is the sole remaining AT-21 in existence and it’s taken me a tremendous amount of time and money to restore. Technically, it has to be flown as single person crew, but the visibility out of the cockpit ‘sucks’ in every direction except straight ahead and to the pilot’s left. Because it is the sole remaining AT-21 in existence, it will possibly end up in one of two museum collections. Besides, it’s such a large beast that I am going to have trouble hangaring it once it starts being reassembled”.

“It’s a hassle sometimes putting an airplane like that on static display. You really have to be careful about security. I remember an old friend who owned a beautiful Mk XVI Spitfire turning around one afternoon to find a kid hanging on the rudder trim tab. Another veteran airshow display pilot from the USA had a solution to the problem of over eager spectators: “I used to carry four signs with me in the gun bays. When I parked the P-51 at a show site, I’d install the stack plugs, pitot cover, (we had a pitot cover that said, ‘high voltage’) and rope off the airplane. Then I’d place the signs around the rope”.

A commonly held opinion is that the vintage aircraft are well past their ‘sell by date’ and that even if the components have never been used, their rack life is expired. In many cases, however, they are every bit as airworthy now as they were when they came off the production line. ‘Sell by dates’ cannot be applied strictly to aircraft that are maintained to such high standards, they do not go ‘off’ with time. As knowledge of materials and methods of detecting weakness in materials (non-destructive testing) has improved over the years, these aircraft are now better understood than when they were first designed. Along with this has come a better understanding of the materials used in WWII aircraft and improved ways of detecting weaknesses within.

Forty years of aero engineering progress has led to many safety and reliability improvements, the main advances have been in the types of materials used for airframe construction, advances in electronics for navigation and in-flight systems management. The engines used in piston-powered aircraft have, however, hardly changed at all. During the era that such aircraft were designed, there was a need to extract more power from them to help achieve high altitude performance and combat. This was done with staged superchargers and running the engines on much higher-octane fuels. Today these aircraft are not flown to the levels of power (boost) that they were designed for and are run on lower octane fuels, the effect of this is that the engines are running well within their design limits.

Add to this the modern methods of inspection and maintenance and you have a very safe combination. The airframes of WWII aircraft were designed to take levels of stress that would be expected from a machine operated to its limits in a combat environment. These airframes are now operated to a much lower level of stress loading. Before anyone says “but they are old now”, yes, but in most cases, the wings have mainly been rebuilt with new spars and are every bit as strong as the day they were built. For example, the Battle of Britain Museum Flight Lancaster had its main wing spars replaced.

Vintage aircraft and ‘warbirds’ have become major airshow attractions in their own right. (Colonel A. Biasus, Brazilian Air Force)

The basic engine in a Piper or Cessna is still the flat horizontally opposed design that it was when they were first introduced many years ago, yet people still fly them across the Atlantic and expect them, with good reason, to be reliable. A good design can withstand the test of time. A typical student PPL learning to fly in a Cessna or Piper is flying an aircraft that might have logged maybe 4 to 5,000 hours of flight time. It may have been designed in the 50's, built in the 70's and have been subjected to the handling of many trainee pilots having been landed in just about every way imaginable. Given the choice of this aircraft or a Spitfire just re-built by experts, flown only a few hours by some of the best pilots in a country, which one would you prefer to fly over shark infested oceans? An interesting observation is that in the analysis of 118 random airshow accidents (Chapter 3), there were twenty-seven vintage aircraft accidents, none of which was due to structural failure. However, six cases of vintage aircraft engine failure were recorded against three engine failures on non-vintage aircraft types.

The basics of aerodynamics have not changed at all, the principles of flight are still the same, the medium within which aircraft fly, is still the same, if maybe somewhat more polluted. Also, our understanding of aerodynamics has improved and this should be transferred to the overall operation of these types, if there is any area for debate, then it could be this. Since there are so few of these vintage aircraft remaining, and because the maintenance requirements are so strict, the cost of each flight hour is very high and therefore they are not flown as much as they should be in the ideal world. This obviously adversely affects pilot currency on type and no design or computer aided solutions can in anyway substitute good old-fashioned 'seat time'.

Training to fly vintage aircraft is not a Federal Aviation Administration requirement. Anyone with a pilot's license that has high-performance and tailwheel endorsements can hop into a Mustang (the non-racer variety) and go; anybody who has taken off and landed the aircraft three times can take a passenger along. The original designers of vintage aircraft used first order principles and 'aerodynamic fixes' to disguise shortcomings and deficiencies in handling qualities. Many of the 'rules of thumb' developed by operational pilots under the duress of wartime flying, have long since been forgotten and are not necessarily passed down to hobbyists purchasing a rebuilt vintage aircraft. Most probably, one of the most dangerous situations arises from the wealthy aviation enthusiast purchasing a rebuild without an experienced instructor to provide the necessary training.

As an example, one of the grave dangers typically posed by the Mustang is its behaviour during an accelerated stall, a loss of lift caused by disturbed airflow over the wing in a high-g manoeuvre like a tight turn. The Mustang can react violently, snapping into a roll and sometimes flipping over on its back, giving the pilot virtually no warning. It is essential for pilots to receive sensitivity training; they need learn to notice the subtle vibration in the stick that precedes an accelerated stall. They also need to learn the procedures for recovering, in other words, the need to learn to 'feel' the aircraft. Perhaps the hardest part of the recovery is that the pilot must be patient enough and obviously have enough altitude to allow the air to resume laminar flow before trying to pull out. Don Lopez, deputy director of the National Air and Space Museum and former Flying Tiger and test pilot, once recalled seeing a pilot get into an accelerated stall in a Mustang in India, recover slightly, pull out too quick, and re-enter the stall. "He did that three times before he hit the ground," he said.

In considering the question of flying vintage aircraft objectively then, amongst the twenty-seven vintage aircraft that crashed over the past years, three of the only airworthy 'one-off' vintage aircraft types such as the Me-109 'Black-6', the B-26 Marauder and the DH Mosquito have crashed. Having listened to both sides of the argument, the gist of the argument must then be fairly cold-blooded and unemotional; if the primary intent is to preserve these aircraft, then it is obvious that vintage aircraft should not be flown. The wisdom of best practice would suggest that the more responsible course of action would be to preserve the 'real thing', and fly the replicas, but you can't preserve and fly warbirds at the same time – these are conflicting goals, a contradiction in terms.

Although the argument may seem trivial, there cannot really be an argument, it is just that in this case, you can't do both. The emotional complexity of the problem however, is that people enjoy owning them and flying them. Taken one step further, the argument is that if people were not buying them and flying them, they would not be around now anyway. If preservation is the objective, especially with 'one-off types', then if you really want to preserve the warbirds permanently, not temporarily, then there is only one option, the unpopular recommendation, stop flying them.

REPLICA VS REBUILD

Taking the argument of flying vintage aircraft at airshows one step further, the next question leads to the question of ‘rebuilds vs replicas’. Within the vintage aircraft milieu, the issue of what constitutes a ‘replica’, ‘rebuild’, ‘restoration’ or ‘original’, is emotive in the sense that the owners/builders have invested hundreds and thousands of man-hours and dollars in their individual projects. In particular, they pride themselves with having produced an aircraft that has aesthetic appeal of historical significance and will in all likelihood, as a side issue, consider the economic benefits of subsequent resale; a replica will obviously not necessarily fetch the same price as a restoration.

Considering the argument about the flying of vintage aircraft, one enters the murkiness of definition; definitions of determining whether, within the preservation process, the particular aircraft is a ‘rebuild’, ‘replica’ or ‘original’. Rebuilding an aircraft by replicating 70%, 80% or even 90% of it from smashed and destroyed bits and pieces is not ‘preserving’ the original aircraft, it is building a replica, but where do you draw the line between ‘rebuild’ and ‘replica’? For the record, the Oxford dictionary defines a replica as an ‘exact copy’ or duplicate and uses terms such as ‘once more’, ‘afresh’, ‘anew’.

In the crash of a P-40 Warhawk in the USA, it’s back was broken in two places, fore of the cockpit and fore of the empennage; the engine was torn away from the mount and the port undercarriage was written off. To repair it, the fuselage longerons were replaced as was the propeller, while the nose and engine had to be rebuilt. In the worst case, 50% of the aircraft was replaced. Is it a rebuild, a restoration or a replica? By definition, it’s not, at the very least, the ‘original’ aircraft.

If the rebuilds that were occurring during the war are considered, broken wings were being pulled off good fuselages and melted down. New wings, or wings from other damaged aircraft were mated on, and the aircraft put back into service, whatever it took to get them back into the air. Those aircraft were, by the argument, also no longer original either. So what is the difference if the repair takes place immediately, or, as in the case of the Aleutian Islands P-40, forty years later? Another angle to the argument is that in the case of restorations, the period technology of the aircraft is just as important as the airframe; there should be a World War cockpit in a World War aircraft! Today, the inside of these rebuilds and replicas mostly have digital avionics and the cockpit is full of modern equipment.

Of course the required modern equipment must be fitted, but it can be done without the hacked-up trashing that often occurs in restorations. One veteran’s comments on restored aircraft: “I went into the Evergreen B-17 a couple of years ago, beautiful bird, but the radio room made me very sad, Navy command sets screwed to the bulkhead.” However, this is quite a different issue from the topic of ‘replica vs rebuild vs original’. For example, what if a pristine B-17 shrink-wrapped from 1945 had a command set screwed to the bulkhead, would that make the aircraft non-original and therefore less worthy? What if the command set is then taken out?

Replicas are sometimes the only way to present historic aircraft when there aren’t any good airframes left, like the Zeros and Oscars that are being replicated. A replica gets built and that goes flying. Consider the example of a P-51D Mustang that as stock issue, doesn’t have room for a jump seat, the original radio is too big. Remove that WWII radio and replace it with a small modern unit and there’s place for a jump seat and the experience of flying a Mustang can be shared with someone else. Would that really be such a bad thing?

The question is: “When exactly does an ‘original’ become a ‘restore’ become a ‘rebuild’ become a ‘replica’?” By definition then, there is no original vintage aircraft left. The P-40K and ‘Black 6’ emotionally lamented as “another original biting the dust” by an aviation enthusiast, may well NOT have been an original by definition. Exactly what then constitutes a ‘restore’? Theoretically, all you would need to ‘restore’ an original Spitfire, apart from inordinate amounts of money, of course, is an authentic manufacturers plate with a serial number on it! The jigs, experience and expertise to produce most warbirds from scratch are there. This is true even of some rarer types.

In an issue of “Warbirds Worldwide”, a restoration company in the UK claims to be able to “tackle any Bf-109 project, no matter what sort of shape the original airframe is in”. Is an original aircraft identity plate enough to turn a replica into an original? Irrespective of what Companies and restorers may claim, No! Is there a certain percentage of original structure below which an aircraft falls into the 'replica' or 'rebuild' categories? No! On the other hand, is there some other way to tell the 'real ones' from the 'fakes'? Maybe! In the final analysis, it is merely semantics since by definition it is neither an original, nor a replica and can therefore only be a restoration or rebuild. A replica is exactly what the dictionary says it is: "an exact copy or duplicate" and may not necessarily be the exact same scale as the original.

But, to complicate matters on flying replicas, there are some strong sentiments on the issue and it is necessary to consider the appreciation of the spectator or veteran in the case of warbirds. To quote an avid airshow attendee: "Seeing a flying replica is not the real thing, it is just a copy and the real thing didn't fly like that". "Seeing a real Spitfire, Bf-109 or whatever, makes heads turn - listening to the purr of a 'real' Merlin instead of some 'suped-up' Jaguar V12 engine, demonstrating the technology of WWII". Well, a Spitfire made out of titanium and carbon fibre composites would not necessarily 'look' different to a sheet metal one if the master templates were done properly, but it wouldn't necessarily fly and handle like the Spitfire we all know. Replicas can certainly be made that are flyable, that is not the problem, but realism and originality are lost.

One of the major challenges to maintaining originality or period equipment in the vintage warbirds, is the question of spare parts. It is very difficult, if not nearly impossible, to get all genuine parts again. There are some parts for which only one or two examples exist in the world and if they fail functionally, they cannot just be ordered again. But why should we restore a plane with genuine parts if it is not intended to fly it later on? If an aircraft is just being rebuilt for a museum, perfectly made static replica parts can be used instead of the original parts.

Still on the question of flying replicas: "Black 6' is a wonderful aircraft that should only be permitted to fly in perfect conditions, no risks. Our children and grandchildren will surely have a chance of seeing a Me-109 somewhere in a museum, no question, but does it really hurt if they see well-made replicas?" At the end of the day, does it really matter? Some connoisseurs of aviation would not like seeing a replica, heaven forbid! It's like the difference between a replica of Michelangelo's David and the real thing.

In closing this rather frustrating argument which tends to go around in circles, it eventually comes down to semantics. But that said, there's something mystical about looking at something and knowing it's the real thing. The design of an aircraft is indeed significant, but one's wonder at its history is amplified to know it was actually there. A favourite piece at the Nimitz Museum in Fredericksburg is their rusty, bomb-damaged Val. The post-war trainer Avenger is in much better condition, but that Val was an actual part of the war, sitting on a runway somewhere when a bomb took its nose off. It makes the events of the day seem real, not just pictures and words in a textbook. You don't get that sense of history from a replica.

CHALLENGES FOR FUTURE AIRSHOWS

From the foregoing it is clear that although airshows continue to provide some of the finest entertainment and is watched by some of the largest numbers of spectators at any given spectator-sport, however, serious challenges exist to the future sustainment of airshows. Unfortunately, no single international body or authority exists to steer airshows along a visionary route of dynamicism with an increased focus on safer performances. There is of course, ICAS and EAC, and although located on two different continents, if there is one point of agreement between ICAS and EAC, then it is that the challenges facing the long-term survival of airshows have changed significantly. To this end, a strategy to win the 'hearts and minds' of airshow enthusiasts and the general public is essential to guarantee the future of airshows.

To achieve the objectives of the stated strategy, ICAS agreed that as from 2003, to focus on certain strategic market areas including the publication of a quarterly news magazine, the publication of a well-planned airshow calendar, the publication of an annual industry guide, Government lobbying, a biennial spectator survey, networking/mentoring and joint marketing programmes.

It took fifteen years of effort to achieve harmonisation of U.S. and Canadian airshow regulations and it has become a possible model for European harmonization as well – in fact, it should become the international model designed for worldwide application. Looking to the future, ICAS additionally undertook to work on intra-industry communications, industry survey programmes, airshow safety programmes, marketing of multiple shows in a single consortium, attendance auditing, the development of national sponsorship programmes and to expand the airshow 'fan base'. In terms of future collaboration, ICAS intended to cooperate even more closely with EAC and to assist EAC in avoiding learning the lessons that it took ICAS thirty-five years to learn. These objectives would be achieved through information exchange programmes to learn from each other, expanding regulatory harmonization efforts to Europe and ready access to ICAS developed documents and literature

Following the EAC 2003 Convention and in the same vein as ICAS, the survival strategy in terms of the European airshows was defined as: "securing the future for airshows". To this end, the critical success factors were divided into seven action areas, ie. Customers, Sponsors, Aircraft, Venues, Profit, Organizers and the Brand. The main thoughts being that a customer can only spend his money once and it was up to the airshow organisers to ensure that that spectators choose airshow events over other mass-events. The competition from the entertainment world is real, airshows do not have a monopoly, and as such it is imperative that airshows offer the best possible 'value for money'. In addition, the customer has to feel safe and convenient, at all times. If the spectacle promised delivers on the quality, the audience will pay the market price! It is thus important to have a good understanding of the customers for whom airshows are being organised - is it the enthusiast or the family?" Shifting the emphasis to 'family' could open new vistas for the airshow world.

In terms of sponsors, EAC advised all airshow participants to ensure that they know the answer to the following question well; "why should a sponsor invest in the specific event?" Greater effort will be required to provide sponsors with information making it worth their while to support a specific airshow; an audit of the audience will become necessary in order to present a sponsor with realistic figures. So who or what products will be prepared to sponsor airshow activities? Aviation related companies will obviously be more than welcome, but the growing market seems to be the manufacturers of consumer products, the brands the widespread airshow audience can easily relate to, products that directly appeal to them. Of course, the retailers must not be forgotten and then of course, the Government - airshows have and will always be needed to promote aviation!

Questions that must be answered are, will there be a place for amateurs in the future, or will the airshow market be taken over by profit making organisations? Is there still going to be scope for some individual efforts? Will the flying clubs be able stay in the airshow industry? Questions which cannot be answered at this stage, but what is for sure is that that there will be further cutbacks on military participants due to budget constraints and operational commitments. Therefore the 'quasi-military', the privately owned jets, will become even more important to the world's airshow community. Sponsored ex-military jets are certainly becoming a regular feature at airshows and while sponsors are readily available to support civilian acts, this mechanism is not readily implementable in the military. The civilian acts have earned their place and will see an increase in airshow contracts, they have become just as important. But in the final analysis, airshow organisers, military or civilian will have to provide enough variety to the flying programme as long as the primary aim is to satisfy the spectators!

In terms of airshow venues, the security issue will become the main aspect in choice of location. Military and civilian airfields will continue to host airshows, but the problems of crowd movement and control to address the issues of security, will have to be approached from new angles and consideration to alternatives will have to be made like seaside shows, country houses, natural arenas, etc.

No pun intended, but the bottom line is that there is no fun in organising an airshow if the final line is red! The input vs return on investment must be carefully balanced and should consider whether the show is a commercial priority or a charity airshow? Are the staff employees, or volunteers? What about coverage of the insurance costs, the airshow participant's costs, in fact, all the other costs versus the total income.

One of the most important considerations in terms of marketing of airshows in future must be, just like any other product in the market that appeals to a widespread audience, that is, to be sure that airshow organisers know well what they represent. Brand awareness will be one of the keys to success. Aspects that must be considered are: “the ‘family’ customer or the ‘enthusiast’ customer; is the airshow presented as a major military event or a warbird show, etc.

So, to answer the question: “Is there a future for airshows”? Yes, absolutely yes! But most likely there will be fewer events, more civilian based content and organised on a far more commercial basis with a larger percentage of the costs being carried by the spectators. EAC estimated that by the year 2010, the UK might typically only offer ten to twenty significant events from June to August each year, some major military shows, some warbird shows, a few seaside shows and following a newer, changed approach, some very different ‘family’ type airshows.

CONCLUSION

Ever since the Wright Brothers’ first successful powered flight at Kittyhawk 100 years ago, it was accepted that all flying would involve an element of risk, but in the world of display flying, a risk even more critical. With the growth of display and demonstration flying since then, those risks have multiplied as pilots and aircraft have been flown to, and often beyond, their respective limits. The number of hours flown annually at flight demonstrations and airshows is an insignificant percentage compared with the total hours flown. Although no accurate consolidated statistical data exists on international airshow accident rates, it is evident that the number of airshow accidents, makes the accident rate for display flying excessive when measured against the universal norm of number of accidents per 10,000 flying hours. It can therefore be concluded that display flying in its various forms can be a hazardous activity for the pilots, the spectators and the public alike.

There are however, many successful display pilots that have survived the airshow circuit in spite of the inherent dangers – their survival can be attributed to concentrated focus on complying with the regulations in force and each pilot’s own strict personal professional creed. The threats imposed by the low-level displays are ever present and there is no means to rid display flying of such hazards – there is only one way to alleviate the effects of the threats, and that is through knowledge, self-discipline and the development of practiced skills. Even then, there can be no guarantee that accidents will not occur. Visitors to airshows will usually be treated to some truly memorable flying and because it is so polished, it is all too easy to forget the degree of skill needed to demonstrate an aircraft effectively.

Pilots have to think carefully about showing off their aircraft to the best possible advantage while always being aware of the risks to safety. Altitude restrictions, the crowd line, local schools and hospitals – everything must be considered and all this while being subjected to heavy doses of negative and positive ‘g’ and very high accelerations; analogous to being blasted off the pad at Cape Canaveral every few seconds in some cases. Whether it is a highly dynamic high-g display, displaying a heavy transport within the confines of a small display area, or even a competition aerobatic display, one thing is for certain, the skills required are world class. So, the next time you watch an airshow, remember that you’re witnessing some of the world’s best pilots at work, the aeronautical equivalent of the Olympic Games, a Broadway Show or a Festival Hall concert – all rolled into one.

To avoid the pitfalls of display flying, the pilot must focus with concentrated determination on the regulations and on one's own strict personal professional creed in order to find the tough narrow compromise between a conservative "wet" display and an "edge of the envelope" super-show. Easier said than done!

(Reproduced with the kind permission of Geoffrey Lee, Eurofighter Typhoon)

CHAPTER 2

OVERVIEW OF AIRSHOW ACCIDENTS

Fouga Magister low flypast at Chateaudun AFB national airshow (France) on 10 May 2003. (Antoine Grondeau)

"As a pilot, only two bad things can happen to you: One day you will walk out to the aircraft knowing that it is your last flight in an aircraft. One day you will walk out to the aircraft not knowing that it is your last flight in an aircraft". (Anon)

INTRODUCTION

On numerous occasions worldwide, thousands of spectators have watched the horror of aircraft accidents unfolding before their eyes. Irrespective of the specific country's status as 'first' or 'third world', military or civilian aircraft, professional or amateur pilot, it is a fact that no culture, creed, or aircraft category escapes the ignominious realm of airshow accidents. Military fighters, large military transports, vintage warbirds, ultra-lights, trainers and flight test prototypes, all feature indiscriminately in excerpts from newspapers, television networks and aviation magazines reporting on some of the horrors of airshow accidents.

The following excerpts are evidence of the hazardous world of display flying. The accidents presented are certainly not comprehensive but rather a random selection of 118 airshow accidents covering the entire spectrum of airshow accidents. The sources of the information include the records of air forces, the NTSB, the AAIB, newspapers, TV video newscasts, Internet discussions and spectator reports. In an effort to achieve conciseness, this section includes only the most relevant information extracts that have bearing on the history, chronology and flight safety aspects of the accidents. Some of the summaries are, therefore, only a few sentences long but others several paragraphs. In an effort to capture and retain, where possible, the real world emotions of airshow accidents, the commentary has intentionally not been taken verbatim from formal accident investigation reports but rather from the open media reports.

What constitutes an airshow accident, what qualifies an accident for inclusion in this database of random airshow accidents? For the purpose of airshow accident analysis then, any flight that is authorised for the sole purpose to practice, display, participate, or use the aircraft in an aviation exhibition, qualifies. The database does not include examples of unauthorised low-level aerobatics of which there are hundreds of examples and are excluded on the grounds that they were not authorised specifically with the view to airshow participation.

10 NOVEMBER 2002: CHANCE VOUGHT F-4U CORSAIR (SOUTH CAROLINA, USA)

The warbird and airshow community in the United States lost another aviation luminary with the untimely passing of F4U-4 Corsair Pilot Joe Tobul in an airshow accident. Performing to a crowd of approximately 70,000 at Columbia Owens Airport's "Celebrate Freedom Festival" in South Carolina, Tobul, 68, reportedly suffered an engine failure, going down approximately one and a half miles off the end of Runway 31.

The aircraft caught fire on impact, resulting in fatal injury to the pilot. Tragically, his son was flying the 'wing' while the formation was positioning for a flypast and watched him go down. Even though the airport had been somewhat hampered over controversies involving noise abatement issues and a no-fly zone over a local coliseum, the event was well attended and well organised. A local media report quoted a Tobul friend as saying, "I understand there was smoke coming out of the engine on a pass as the plane came across the field for the airshow. A lot of people thought it was airshow smoke, but a Corsair doesn't have airshow smoke. There was some kind of failure in the engine. It apparently got out the way of homes and trees but then crashed in the swamp." The airshow continued shortly after the accident, although no word of the fate of Tobul was released during the show.

The Chance Vought F4U-4 Corsair, named *Korean War Hero*, had retained three combat flak repair patches on the starboard wing and rear fuselage area and had served two tours of duty with over 200 combat missions, before being retired from Naval service on 5 July 1956. From approximately 1960 to 1970, the aircraft flew with the Honduran Air Force. In 1970, it was sold to an American Airline pilot and brought to the USA before Joe & Jim Tobul bought the aircraft in 1981 and started a very long rebuilding project. Ten years later, *Korean War Hero* proudly flew again on 8 December 1991 and had been a major presence at airshows all over the country.

01 OCTOBER 2002: ILYUSHIN-38 (INDIAN NAVY, BOMBAY, INDIA)

The Indian Navy suffered its worst disaster in its aviation history when two Indian Navy IL-38 maritime patrol aircraft practicing for the upcoming anniversary airshow, collided in mid-air in the western state of Goa, killing twenty-two people. The Russian-made Ilyushin-38 maritime patrol aircraft were performing a close formation flypast for the airshow to mark the 25th anniversary of the Indian Navy's 315 Air Squadron.

The two aircraft, each carrying six crewmembers, took off from the resort state's main airport in Panaji and collided with each other in echelon formation over the nearby area of Zuarinagar while positioning for the flypast. One of the aircraft impacted on a road and the other on a building that was under construction. Most of the dead were aircrew members but sadly, three labourers were killed and seven injured by crash debris at the building site.

The Panaji airport was immediately shut down and all flights in and out delayed. "Although standard operating procedures were in-force, which included height and separation distances of the aircraft, for some reason, the two aircraft came closer and collided in mid-air. "It could be because of an error in judgement, malfunctioning or catastrophic failure of the control", said Chief of Naval Staff, Admiral Madhvendra Singh".

21 SEPTEMBER 2002: HARVARD T-6G (SAAF MUSEUM, AFB WATERKLOOF, SOUTH AFRICA)

Leading a four-ship formation from the South African Air Force Museum's vintage collection of Harvard, Aermacchi AM-3 Bosbok, Atlas Aviation Kudu and Piaggio P-166S at the Africa Aerospace and Defence Exhibition 2002, the Harvard suffered a catastrophic engine failure. Just after turning out left and at approximately 1,500 ft agl, the leader, Colonel Geoff Earle radioed that the Harvard engine was vibrating excessively and loosing power rapidly. The rest of formation was still in line astern in the process of forming-up.

While turning right hand about, the pilot tried to find a 'sweeter spot' with the throttle and called that he was going for an off-field, forced landing. The Bosbok, acting as airborne search and rescue co-ordinator followed the stricken Harvard down and took over the rescue communications while Earle selected a field and set up for the landing with undercarriage up.

At approximately 30 ft agl, the pilot selected full flap (very short field) and at this stage he reported a loud grinding noise from the engine and then the propeller stopped dead, inducing a very sudden increase in the rate of sink. The left wing then clipped power lines spinning the aircraft flat through approximately 160º before bouncing hard on the ground, the impact ripping off the pilot's flying helmet in the process. On the next bounce, the aircraft came to a rapid stop, only 30 metres from the original contact point with the power lines. The aircraft caught fire on impact resulting in burns to the pilot's face; he also suffered a broken rib and a cut on the lower jaw from control stick. The aircraft burnt out completely, resulting in Category 5 damage.

The Bosbok pilot now controlling the search and rescue effort saw the pilot egress safely and the rescue chopper reached the pilot within eight minutes, getting the pilot to the nearest Military hospital in 42 minutes. The formation then rejoined and continued the flypast without further incident.

02 AUGUST 2002: BAE HARRIER GR 7 (RAF, LOWESTOFT, UK)

An RAF Harrier GR7 of 20 Squadron RAF Wittering, crashed into the sea at the Lowestoft annual airshow on 02 August 2002. Nearing the end of the display sequence in the hover and preparing for the 'bow' in front of the 40,000-strong crowd, a loud engine 'explosion' was reportedly heard by spectators, the Harrier lost power and descended rapidly from the hover. The Harrier is loud, but the explosion left no doubt that it was *not* part of the act. At about 50 feet above sea level, the pilot Flight Lt. Tony Cann, ejected.

The pilot's chute opened just in time to complete one pendulum before he landed on the sinking Harrier, the pilot breaking his ankle on impact with the aircraft. Had the accident occurred over land and the aircraft exploded, the pilot would most certainly have landed in the post impact fireball. The pilot was immediately picked up by a rescue dinghy before being transferred to Lowestoft Lifeboat. Within minutes he was winched aboard an Air-Sea Rescue helicopter and waved to the crowd before being flown to hospital for a routine check up. Nobody else was hurt in the accident and the show resumed about thirty minutes later.

27 JULY 2002: SUKHOI SU-27 FLANKER (UKRAINE AIR FORCE, SKNILIV, LVIV)

Just when airshows worldwide appeared to have achieved a standard in which the safety of spectators was no longer jeopardised by display line incursions, a Ukraine Air Force Su-27 crashed into a spectator enclosure at an airshow killing 85 people (including 27 children) and injuring more than 156 making it the most disastrous airshow accident in the history of the airshow circuit. The accident occurred at Skniliv airfield in the western Ukrainian city of Lviv to mark the 60th anniversary of the 14th Air Division of Ukraine's air force.

Approximately two minutes into the display routine, the aircraft was in a left hand, level steep turn when suddenly it over-rolled through approximately 200º to the nose-low inverted position from which the pilot proceeded to pull out from. Now twisted off the show line directly at the spectator enclosures, the pilot could not recover due to insufficient height. It is highly unlikely that this manoeuvre was intentional since no pilot in his right mind would have attempted this 'half-roll pull through' from such a low height.

In a 'deja-vu' of the 1999 Paris Airshow Su-27 low-level ejection, both pilots, Toponar and Yuri Yegrov, his co-pilot, survived the ultra-low ejection but suffered fractured vertebrae. The pilots ejected only after they had exhausted all options at preventing the aircraft from crashing into the spectator enclosures, a possible indication that they were struggling to get control of the aircraft and steer it away from the spectator enclosures. Spectators watched in horror as the aircraft smashed into onlookers and ploughed across the airfield before bursting into flames. Dazed and bloodied survivors of the tragedy looked in shock and horror at bodies of the victims strewn over the ground.

All aspects of the preparation of the show and responsible personnel actions were investigated, as well as the radio communications with the ground. From reports emanating from the investigation it emerged that the flight crew did not have a flight card and had not been briefed about the features of the airfield. Even more amazingly, there had been no practice flights flown over the display area prior to the display.

Certainly a sad indictment of poor supervision if ever there was one. When the aircrew violated the display zone, the ground controller did not warn them and even after they had performed the very first loop and it became obvious that they were extremely close to the crowd, neither of the Display Controllers in contact with the aircraft took steps to instruct or inform the pilot of the show line incursions. Furthermore, the flight data showed that the manoeuvres were flown at an altitude lower than 200 metres, which was below the airshow lower limit.

Gross negligence and poor supervision resulted in an enraged Ukrainian President, Leonid Kuchma, immediately dismissing the Chief of the Air Force and the Airshow Organiser and banned all further military airshows. Speaking at the site of the tragedy, a shocked Kuchma said that the air force should concentrate on their military duties rather than performing for crowds. "In my opinion we need to stop these kind of air performances. People should do their military business and should train, not take part in these airshows," Kuchma told local television stations. Kuchma refused to accept the resignation of the Minister of Defence. (Chapter 4 provides a comprehensive overview of the politics involved in this particular accident)

20 JULY 2002: FIAT G-222 (ITALIAN AIR FORCE, ROYAL INTERNATIONAL AIR TATTOO, FAIRFORD, UK)

Demonstrating an assault approach and short-field landing at RIAT 2002, the pilot of an Italian Air Force medium-lift Alenia G-222TCM, misjudged the rate of descent on the steep approach, flared too late and landed heavily on the nose-wheel, bounced and then forced the nose-wheel down to enable application of wheelbrakes and reverse thrust. The force with which the nose-wheel contacted the runway pushed the nose-wheel assembly right into the cockpit, the sparks caused by the

The sparks from the Italian Air Force's G-222 ignited a hydraulic fire which extinguished itself once the fluid had been exhausted. (Col A. Biasus, Brazilean Air Force) airframe scrapping on the runway were sufficient to ignite a small hydraulic fluid fire in the wheelwell. In addition, a liquid oxygen container ignited inside the aircraft during the impact and burnt fiercely. The crash rescue services were quickly on hand to extinguish the fires. Fortunately the aircraft did not depart the runway, which could have induced asymmetrical forces with consequent catastrophic failure. Minor damage was inflicted on the aircraft with no collateral damage caused to infrastructure. The airshow was delayed for approximately two hours while the crash rescue services removed the aircraft from the runway using cranes and airbags.

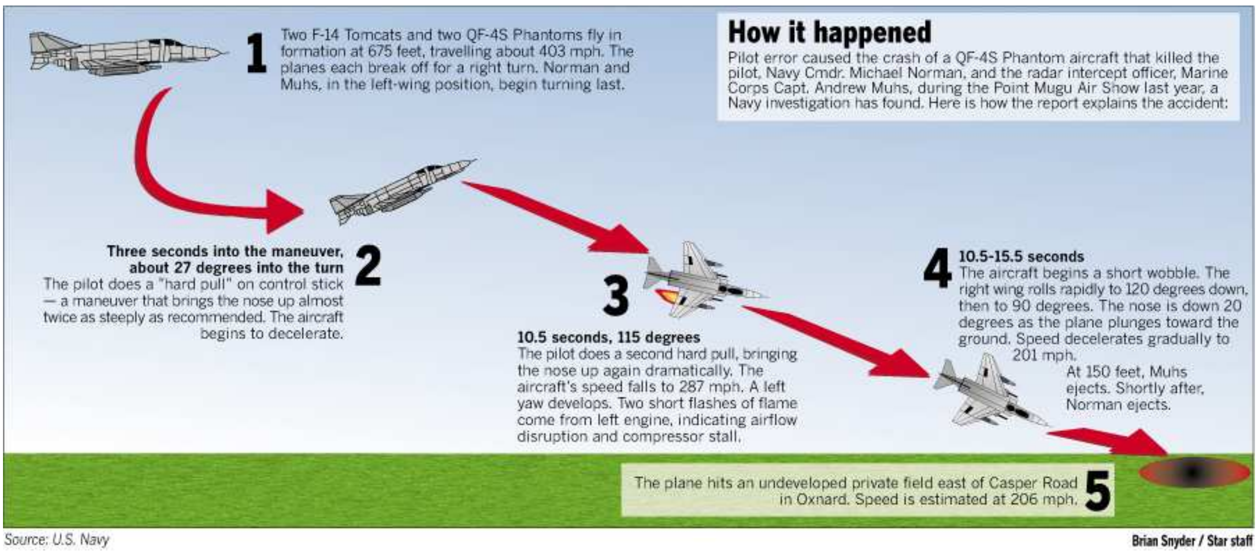
23 JUNE 2002: RUTAN ACROEZE (PATROUILLE REVA, NANCY, FRANCE)

One of the three Rutan AcroEze aircraft of the French civilian team Patrouille Reva, crashed at Nancy Airshow, France, killing the pilot, Michel Coste, a 49 year-old ex-military pilot. An eyewitness reported that the team had just executed a triple break when the right wingman's aircraft wingtip struck the ground sending the aircraft cartwheeling into trees, away from the public enclosure. The Rutan AcroEz is an enhanced version of the original VariEz, including strengthened airframe and a more powerful engine.
The airshow ceased immediately after the crash, but resumed approximately ½ hour later with Patrouille Cartouche Doré performing their display. The team were scheduled to perform at the Colmar-Meyenheim Airshow in France just one week later but understandably, did not perform at the show, instead the remaining two aircraft arrived at Colmar in the late afternoon and made a single flypast with smoke on as a tribute to their 'fallen' colleague.

20 APRIL 2002: F-4 PHANTOM (USN, CALIFORNIA, USA)

A QF-4S Phantom II, assigned to the Naval Air Weapons Test Squadron at Point Mugu crashed during the 38th Point Mugu Airshow (CA), killing its two-crew members, Navy pilot Cmdr. Michael Norman, 39, and radar intercept officer, Marine Capt. Andrew Muhs, 31. Spectators, watched in horror as the Phantom, in a right hand turn at approximately 400 ft, exhausted a sudden vapour stream followed shortly thereafter by two short bursts of flame from the jet pipe. The aircraft crashed in a fireball about a quarter of a mile away, in a secluded area west of the base. There were no injuries on the ground and fire crews took ten minutes to extinguish the fire. The show was cancelled and the thousands of spectators were asked to leave the base and although it was announced that the show would continue the next day, on Sunday, it was eventually cancelled completely.

The accident aircraft was flying on the left of a four-ship diamond flypast in straight and level flight. Each aircraft individually pitched into a standard right-hand break, one at a time,



Graphic depiction of final seconds of the QF-4S. (Brian Snyder, Ventura County Star, Ventura, California. ("Reprinted from the Ventura County Star.")

leaving the formation as if they were peeling-off for landing. About two seconds before the turn into the break, the F-4 began streaming continuous white smoke from one of the engines - not a huge gush, but there was a very clear trail visible in the sky. Established in a steep right bank the QF-4S seemed to be maintaining altitude at that time and with the smoke trail still visible, two small balls of flame were suddenly expelled from the jet pipes in quick succession. They were not tongues of flame licking out of the aircraft, but rather just little balls of fire that 'spat' from the aircraft as it continued moving through the turn.

Immediately after that, the F-4 experienced large roll excursions, at one point rolling almost inverted, estimated at 150º bank to the right during one of the excursions. The bank angle decreased significantly under what appeared to be the pilot commanding the recovery roll, but did not reach the wings level attitude. The bank increased again to about 90º, all the while in a rapid descent that was maintained right up to impact. It did not appear as if the pilot was able to command the wings level attitude or break the descent rate. Just before impact, the aircrew ejected.

The considered opinion of a former F-4 driver: "The mishap aircraft was last in the formation. The aircraft was seen proceeding ahead taking normal break spacing, then a stream of white vapour pulsed from both engines, probably indicating burner selection in anticipation of an ultra-tight break for the crowd. The burners didn't light but the pilot continued the break anyway. At high 'g', the aircraft was decelerating rapidly and the airflow through the intakes at high AOA was sufficiently disturbed that no afterburner light-up occurred".

"Then, the combination of fuel in the burner cans and ignition 'popped-off' creating a severe compressor stall in both engines causing the brief flash of flame seen in the hard right turn. In a high bank angle, decreasing airspeed and high sink rate, the back seater initiated ejection, but the zero-zero seat capability could not overcome the downward vector and the occupants separated from the aircraft just prior to impact." Comment by another experienced F-4 driver: "Both engines appeared to flame-out and then it dropped like the brick which the "spook" is well known for at low airspeed. The F-4's survival and existence was speed, it could only do so much when at high speed, but at the low speed end of the envelope, the F-4 was risky, ask any 'rhino' crew. Sad way to see a forty-year old MiG killer with Vietnam experience go down, but at least it survived 'droning', only to be lost in a non-operational mission".

The official US Navy report, compiled by a team of investigators from the Naval Weapons Test Squadron at Naval Base Ventura County, assigned 'Pilot Error' as the primary cause and ruled out mechanical failure, birdstrikes or faulty maintenance as causes of the crash. The report blamed Norman's handling of the jet of the run-in break manoeuvre and the veteran pilot's relative inexperience with F-4 aircraft. Although Norman had racked up more than 3,300 hours of flying time in military jets during his 16-year career, he had logged just 79 hours flying the QF-4S, an experience level that was considered "below average," by the Board.

The investigation report, obtained by *The Star* through a Freedom of Information Act request, detailed how Norman aggressively pulled the QF-4S Phantom II into the break from a diamond formation flying at approximately 350KIAS and at 675 feet above ground level. In the process, the pilot exceeded the stall angle causing the aircraft to decelerate rapidly, the investigation concluded. To recover, the flight manual called for the pilot to decrease the angle of attack, but Norman once again pulled aggressively. The initial hard break into the turn exceeded the briefed g-level for the practice and airshow flyby. The reason for the second hard pull was indeterminable although it may have been an attempt to 'square the corner' of the turn to give the appearance of a sharp break, the Board surmised.

After the second pull, the engine suffered a compressor stall causing two short flashes of flame from the left engine that prompted initial speculation that the 34-year old aircraft had suffered a mechanical malfunction or bird ingestion. Having entered the ragged edge of an accelerated departure, the jet began to wobble, rolling through to 120º then to a nearly inverted position. The pilot was able to recover transiently to 90º and get the nose pitched down, but the aircraft plummeted to the ground taking just five seconds from the moment the aircraft departed until impact.

The crewmembers had no real opportunity to eject safely, investigators found, Muhs, 31, ejected at 150 feet, followed by Norman at nearly ground level. Investigators found that the ejection mechanisms were serviceable. Video footage showed the back-seater clearing the jet seconds before it hit the ground in front of 25,000 spectators but his parachute never deployed fully and he plunged through a huge fireball into the ground. The autopsies showed that the cause of death to both aircrew was attributed to blunt-force trauma from striking the ground. Wreckage was strewn over a swath 350 yards long and 100 yards wide.

Investigators furthermore concluded that Norman did not account for the weight of 8,000 pounds of fuel on board, which was about 4,000 pounds more than the aircraft was carrying during a practice run three days earlier. The sharp break manoeuvre and the resultant fuel shift had moved the Phantom's centre of gravity further aft and there that there was no discussion of the heavier weight among the pilots before they broke into the turn, something that should have occurred, investigators suggested. It was suggested that although an experienced aviator would normally allow for the different fuel condition and adjust as needed to fly the aircraft, more awareness about the inexperience of the pilot with regard to the heavy landing condition should have resulted in calls before the break such as, "QF-4s, we're heavy, watch the pull," the report states.

The investigation's findings prompted Navy officials to increase minimum experience criteria for pilots in Point Mugu's QF-4 programme. Only pilots with a minimum of 200 flight hours on F-4s of all types and 600 to 800 hours of tactical jet experience, including flying in formation, would in future be assigned to fly the QF-4S. Under the new standards, Norman would not have been allowed to fly in the airshow. As a result of the crash, the F-14 Tomcats and QF-4S would no longer participate in future Point Mugu airshows. Whether the show would be held in 2003 also remained uncertain largely because of difficulty of booking a military jet precision flying team such as the Navy's *Blue Angels*.

11 APRIL 2002: ALPHA-JET (FRENCH AIR FORCE, *PATROUILLE DE FRANCE* , FRANCE)

The number 4 pilot, Flt. Lt. Daniel Marchand, who was destined to become team leader of *Patrouille de France* in 2003, was killed when his Alpha Jet crashed at a military base in the Salon-de-Provence in southeast France at the end of a rehearsal. No other collateral damage occurred. The pilot was able to eject from the aircraft, but died when his parachute failed to open completely, being outside of the ejection seat envelope at ejection.

28 MARCH 2002: HAWK MK 53 (INDONESIAN AIR FORCE, *JUPITER BLUE,* INDONESIA)

Four pilots were killed when two Indonesian Hawk Mk. 53 jets of Indonesia's elite *Jupiter Blue* aerobatic team crashed after clipping wings during rehearsals for an upcoming airshow. The accident occurred in good weather near Iswahyudi Air Force base in Madiun, about 375 miles southeast of Jakarta while attempting a 'victory roll manoeuvre' around the leader.

A witness reported that: "The aircraft were flying in the same direction and collided with each other when they attempted to cross each other's paths at approximately 2,000 feet above ground level, both aircraft bursting into flames when they hit the ground, killing the two pilots and their co-pilots. There were no ejections, just a big sudden boom when the aircraft collided during the manoeuvre", the witness said.

Subsequent to the Ukrainian Air Forces' Su-27 crash in July 2002 in which eighty-six spectators were killed and more than 156 injured, Indonesia's *Jupiter Blue* precision flying team was grounded by order of the air force commander, Marshal Chappy Hakim. The pilots were prohibited from flying displays or even, according to reports, display training flights. He said they were grounded, "pending the examination of the mental state of the pilots and the physical state of the aircraft." Indonesia's air force had recently been hurting for funding and pilots were down to flying just fifteen flying hours a month, about a quarter of what had previously been allotted.

The frustrations of the Air Force Commander can be understood in light of the fact that Indonesia's fighter pilots had previously crashed three Mk. 53 Hawks (one, a member of *Jupiter Blue* , in a midair collision at the end of March). The Marshal concluded that there just wasn't enough flight training going on so he grounded the team.

8 MARCH 2002: F-16A (PORTUGUESE AIR FORCE, MONTE REAL, PORTUGAL)

An F-16A of the Portuguese Air Force crashed just short of the runway at Monte Real in Portugal while practicing a loop for an upcoming airshow to celebrate the 50th anniversary of the Portuguese Air Force. The height available for the recovery pull-out was insufficient, the pilot, Capt Pilav Horge Moura did not eject and was killed in the crash. Unusually, the aircraft was configured with underwing fuel drop tanks for the practice display.

5 FEBRUARY 2002: HAWK MK 65 (RSAF, SAUDI *GREEN FALCONS*, SAUDI ARABIA)

Two Hawk Mk. 65A aircraft of the Royal Saudi Air Force *Green Falcons* aerobatic team collided during a formation landing practice for an upcoming airshow. The accident occurred while the aircraft were on approach to their home base of Tabuk and although both pilots escaped with only minor injuries after ejecting, four members of the public suffered minor injuries when the aircraft impacted inside an Army base.

16 JANUARY 2002: CM.170 FOUGA MAGISTER (EL SALVADOR AIR FORCE, SAN SALVADOR)

Colonel Milton Andrade, the commander of the Air Force was killed when the Fouga Magister he was flying crashed onto the runway and exploded while practicing for an upcoming airshow.

17 OCTOBER 2001: (EDGE 540, KIRBY CHAMBLISS, CHINESE GRAND PRIX, JILIN CITY, CHINA)

Kirby Chambliss, former 1998 U.S. National Aerobatic Champion, crashed into the Jilin River during his display at the 2001 Grand Prix in China. The aircraft impacted into the river at approximately 200 mph after a ‘turn-around’ manoeuvre but due to the excellent response of the emergency services put in place by Jilin City, Kirby was quickly rescued from the water and taken to the hospital. Although he did not have any broken bones, he received several cuts to his head and face. Chambliss not only recovered from his superficial injuries, but went on to be named US National Aerobatic Champion at the US National Championships in 2002.

24 AUGUST 2001: T-6 HARVARD (NEW MEXICO, USA)

Airshow pilot, Minor ‘Scoop’ Smith of Rio Rancho, New Mexico, was killed along with his passenger during a pre-show practice flight before the Raton, New Mexico airshow. Eyewitnesses stated that Scoop was performing a ‘hammerhead stall’ but lost control and was unable to effect recovery due to the low altitude of the manoeuvre. ‘Scoop’ was the husband of Julie Phile Smith, a past member of the U.S. Aerobatic Team.

9 JULY 2001: HAWKER SEA FURY (SARNIA INTERNATIONAL AIRSHOW, CANADA)

Airshow pilot Carey Moore was killed when his Hawker Sea Fury crashed while performing at the Sarnia International Airshow in Ontario. Eyewitnesses reported seeing the aircraft enter an incipient spin from a climbing turn after a slow airspeed, low-level pass. No one on the ground was injured in the accident but his fourteen year-old son, along with thousands of spectators, watched in horror as the vintage aircraft crashed.

“He had taken off and had completed two passes and was setting up for his third pass,” said Blake Evans, air-boss for the show. Evans was asked about safety precautions in the wake of the recent Canadian Snowbird crash in Lake Erie (21 June 2001) and the Biggin Hill Airshow tragedies of 2/3 June 2001. “All of the safety regulations were given to the flight crews at this show as they are at all the shows we do, both yesterday morning and this morning,” he said. The pilot had a lot of time on T-28’s and similar category aircraft, and about 21 hours on the Sea-Fury. The question that begged asking was: “Is 20 hours on type sufficient to be putting on a public display?”

The aircraft went down in a soybean field in front of a farmhouse, east of Chris Hadfield Airport, shortly after 2 p.m. A witnesses said: “the aircraft banked over the farm, the left wing on the aircraft was high as it turned then dropped and impacted like a folded accordion on the ground". "It just looked like it rolled over, the last thing I saw was the blue belly of the aircraft before it went down into the trees".

The force of the impact was clear from the damage; most of the aircraft was unrecognisable. The rudder was still intact though, as was one of the five prop blades that stuck out of the ground. A shaken Tom Walsh, ex-manager of the Biggin Hill International Airshow, said it was too early to say whether there would be another show the following year. "We would hope that it would be but the matter is in the federal agency's hands at this point," he said. Walsh said that he had never had a fatality at any show he had organized. "I've been doing this for twenty-eight years and this is the first," he said. No one else was injured in the crash.

Jim Foubister, a Sarnia city councillor who was at the airport, also said it was too early to say if the city would still support the show, then in its third year. "Today is probably not the day to make that decision," but said the operation is "first-class" and had his support. In an interview with a Sarnia newspaper, Walsh said he wasn't overly concerned about the safety of the event as his co-ordinators tried to keep it as safe as possible. "There's always a likelihood of something going wrong," he said. (Free Press Reporter & Special to The Free Press, Sarnia)

This particular Hawker Sea-Fury FB Mk.11 was a fighter-bomber version of an aircraft designed for the Royal Navy in the early 1940s. The piston-powered aircraft entered the service in 1947 and flew with distinction during the Korean War and remains the fastest piston engine aircraft ever produced. Moore Aviation Restoration in Breslau, east of Kitchener, owned the Sea Fury and was one of only twenty-six in the world still flying. It started its military life in 1947 with 802 Squadron of the Royal Naval Volunteer Reserve and served in Korea in 1952, recording 165 bombing missions, and four air-to-air kills, including two unconfirmed victories over Korean MiG-15 jet fighters. After the Korean War, the aircraft was rebuilt and sold to the Iraqi Air Force. Purchased privately in 1972 in the USA, it was restored to museum quality in 1995 before arriving at its permanent home in Canada.

18 JUNE 2001: FOUGA MAGISTER (WISCONSIN, USA)

As a wedding present, a newly married woman, Sara Hanson, was given a flight in a Fouga Magister that unfortunately crashed, killing her along with the pilot Roger Simpson of Northville, Mich. during a pre-airshow flight. Spectators at the Deke Slayton Airfest, at La Crosse, Wisconsin, USA, watched as the aircraft lost a section of the wing and plunged to the ground, bursting into flames. Hanson had been married the previous Saturday and her husband, had flown in the same jet on the previous day as part of the plane ride gift, the La Crosse Tribune reported.

The Fouga took off on runway 21 and not too long after that, it approached the airport from the north setting up for a low pass down runway 18, at approximately 500 ft. As the aircraft passed the mid-field point, the jet pitched up slightly and almost at the same instant, a wing separated, the rest of the aircraft rolled violently before hitting the ground. A witness recounts: "The explosion was loud enough and the fireball large enough that I just instinctively knew no one survived the impact. The whole thing happened in a flash - it couldn't have been more than three or four seconds". The French-made two-seat military trainer, one of more than seventy in the USA, was participating in the two-day air festival; no one else was hurt.

The FAA preliminary report stated that: "On a low pass the left tip tank broke off, followed by progressive disintegration of the aircraft, crashing on the south side of the airport near the perimeter road." Dick Knapinski, spokesman for the Experimental Aircraft Association out of Oshkosh, Wis., said: "the aircraft is subject to FAA inspections that are conducted yearly or every 100 hours of flight. Whoever owns those things are very meticulous with inspections, it's just the nature of those owners," he said. According to FAA records, Simpson's Fouga was manufactured in 1959, was declared airworthy on 18 December 1995 and had been registered to Simpson since 4 March 1998. The Fouga was first produced in France and served the French Air Force until the 1980s. To quote a warbird owner: "There is always a risk when flying 40-year-old aircraft at high speeds. When owners fly them at airshows, they have the risk that goes with low-level aerobatics – most pilots know that".

10 JUNE 2001: L-39 ALBATROSS (RUSSIAN AIR FORCE, *TEAM RUSJ*, RUSSIA)

The Russian Air Force's L-39 Albatross *Team Rusj* took off in two groups of three aircraft to begin their display at an airshow at Levashovo Military Field in St. Petersburg, Russia. While the six L-39s were about 5km away positioning to start the run-in, there was a bright flash from the formation and then a cloud of black smoke. Two aircraft were seen breaking away from the formation and fell to the ground with clouds of black smoke rising from a forest. The airshow was immediately stopped and the authorities expelled all spectators from the airfield. The rest of the team landed, the two aircraft that were missing were aircraft No.5 and No.7".

Both pilots ejected from their aircraft and while one was found almost immediately and was alive, the body of the other pilot, 42-year old Sergey Maksimov, was only found at 8:40 p.m. that evening. Although he had ejected, his aircraft was inverted and at such a low altitude, was outside the seat ejection envelope - the ejection seat was found embedded in the ground. The remaining two days of the St. Petersburg airshow were cancelled".

21 JUNE 2001: CT114 TUTOR (RCAF *SNOWBIRDS*, ONTARIO, CANADA)

The Canadian 431 (AD) Squadron "*Snowbirds*" were conducting a media flight two days prior to performing at the London Airshow in Ontario. Each of the nine aircraft had a pilot and a passenger on-board. Lead and aircraft No.5 had broken away from the remaining seven aircraft in a 'Concorde' formation for some photographic opportunities of the Lead aircraft and had begun their rejoin to the main formation.

As the rejoin proceeded, pilot No.5 broke away from aircraft the leader to take up his normal position in the main formation. The lead aircraft simultaneously manoeuvred to position to re-take the lead of the main formation. The two aircraft collided approximately 100 metres behind the main formation. The leader of the formation, Major Bob "Cowboy" Painchaud lost control of the aircraft and commanded an ejection, landing in Lake Erie approximately 2.5 km from the shoreline. The No.5 aircraft remained controllable and the pilot was able to land the damaged aircraft at London airport without further incident. Both the formation leader and the passenger were recovered from the water by a Labrador helicopter stationed at 424 Sqn Trenton, Ontario approximately one hour later.

The lead aircraft sustained Category 'A' damage due to the mid-air collision and a post ejection fire and was subsequently destroyed on impact with the water. Aircraft No.5 sustained 'C' category damage, a portion of the right wing leading edge was missing, the right hand aileron was bent at the outboard attachment point, the wiring, pitot/static lines and the wing spar, was damaged. (Canadian Defence Flight Safety)

4 JUNE 2001: SPITFIRE (ROUEN VALLÉE DE SEINE AIRFIELD, FRANCE)

Eleven Spitfires and a Hurricane were taking part in the airshow at Rouen Vallée de Seine airfield in northern France, the first occasion such an important collection of vintage aircraft had been brought together in France since World War II. At the time of the crash, there was general reporting in the UK to the effect that, following power failure of the engine, Martin Sargeant (56) had initially attempted to land on the grass runway designated for emergency use, but had been unable to do so due to spectators having spilled onto this area.

In an attempt to realign the aircraft on the active hard-surface runway, the aircraft stalled and auto-rotated in from a very low altitude, exploding on impact. The Spitfire was destroyed and Sargeant was killed. It was the third fatal airshow crash in as many days in UK/Europe, following on from the deaths of three aircrew in the space of twenty-four hours at Biggin Hill airshow in Kent (UK) on the previous two days.

All three crashes involved Second World War aircraft, which obviously raised questions about the safety and logic of flying vintage aircraft. One witness said that the pilot had narrowly avoided crashing into the 10,000-strong crowd at the airshow. Fireman Yannick Bobin said: "Earlier we had seen smoke coming from his engine and the airport siren was rung. The pilot wanted to land on the runway, but at the last moment when he saw he would crash into the spectators, he turned away to avoid them".

The June 2002 edition of the magazine *Aeroplane Monthly* published the outcome of the French enquiry, including the contents of a letter from the Rouen Public Prosecutor to Sargeant's widow. This details the cause of the crash, inter alia, incremental engine failure and occupation of the emergency runway by spectators, preventing an emergency landing. The decision then to try to use the active runway despite of the engine failure, led to rapid energy loss leading to a stall. The final attempt to correct an uncommanded roll with ailerons, exacerbated an already impossible situation. The above points have been précised from the magazine article, which claims to have reported the text of the letter written to Mrs Sargeant.

The magazine goes on to suggest that there are significant issues not covered by the official report, in particular, why the emergency runway was accessed by spectators, and what the role of the Flight Director was during the period between the first report of trouble and the crash some 2.5 minutes later. *Aeroplane Monthly's* editorial was also critical of the role of the display Flight Director and also about the failure of the authorities to bring any charges or issue directions for the safety of future events.

03 JUNE 2001: BELL P-63 KINGCOBRA (BIGGIN HILL, UNITED KINGDOM)

On 03 June 2001, one day after the fatal accident at the Vampire at Biggin Hill 'Air Fair', billed as a celebration of US aviation heritage, a 60-year-old Bell P-63 Kingcobra crashed. The pilot, Guy Bancroft-Wilson, 43, a British Airways captain was killed in the crash. The organisers had advertised the Bell Kingcobra as a late addition after a long-booked Russian Su-27 aircraft had cancelled at short notice.

About five minutes into the sequence, the third aircraft of the trio of vintage fighters, the Kingcobra, pulled up into a vertical manoeuvre and then entered a spin from which it failed to recover from and crashed in clear ground to the north west of the runway, just 100 yards away from horrified onlookers. The Kingcobra, 'appeared to stall' during an earlier vertical manoeuvre in the sequence and the pilot was instructed by the Display Committee to land. Unfortunately, the communications relay from the Flying Control Committee to ATC failed at precisely that time and some seconds later, the aircraft stalled again at the top of a loop and entered a spin from which the pilot did not recover.

The P-63 Kingcobra, from a celebrated breed of World War II fighters, was built by Bell in the US and had recently been restored in Britain. The rest of the International Air Fair was suspended and the airfield closed following this second accident. Airshow spokesman Nick Smith said the two crashes were "extremely unfortunate", but defended the safety record of vintage airshows, saying the last fatality at such a show was in 1980.

The general public and media in the UK were shocked and stunned that two pilots and a safety pilot could have lost their lives in two days. A witness from Crayford, Kent, was filming the event when the plane crashed. He said: "I was filming the plane with my video recorder when I saw it lose control and turn over on its back. It then fell to the ground and there was a huge explosion of flames and smoke, the pilot would not have stood a chance." (The AAIB report is addressed in some detail in Chapter 4)

02 JUNE 2001: DE HAVILLAND VAMPIRE (BIGGIN HILL, UNITED KINGDOM)

On Saturday, 2 June 2001, the De Havilland Vampire, flying in close trail behind a De Havilland Sea Vixen, was halfway through the day's final display when it spiralled out of control and crashed about a mile and a half from the packed airfield near Bromley, Kent. Nobody else was injured although several witnesses suffered shock but declined medical treatment.

The aircraft, owned by the De Havilland group, was a 1950s fighter trainer aircraft that had been restored and formed part of the De Havilland trio of Sea Vixen, Venom and Vampire. The 1950s former Swiss air force jet-trainer had flown past the crowd four times and was in a tight turn trailing behind the much larger Sea Vixen when it hit the Vixen's slipstream and "flicked-in", auto-rotating before plummeting into a ridge. The large vortex shed from the much larger Sea-Vixen, coupled to the high wing loading of the Vampire, was considered a contributory cause to the uncommanded departure from controlled flight.

The pilot, former British Deputy Chief of Defence Staff, Sir Kenneth Hayr, 66, and Mr Kerr, 32, the safety pilot, were killed instantly. A holder of the Air Force Cross and Bar, Sir Kenneth commanded the first RAF Harrier squadron in 1969 and was knighted twice, including in 1991 for his role in the Gulf war. The safety pilot in the right seat of the Vampire, was qualified on type but his presence was merely to assist with lookout as the view from the left seat was restricted. Civil Aviation Authority permission had been granted for the use of a safety pilot under these circumstances.

After members of the dead pilot's team were consulted, it was decided that the second day of the International Air Fair, which was in its 39th year and annually attracted around 35,000 people, would continue.

This was not the first kind of dissimilar formation accident. On 25 May 1986, the RAF Vintage Pair were engaged in an air display at RAF Mildenhall, which was to include the Meteor leading the Vampire in formation line-astern barrel roll to the left. The display went according to plan until the aircraft reached the top of the formation barrel roll when the Vampire was unable to match the Meteor's rate of roll and became displaced down, left and slight back from the line-astern position. The Vampire then moved forward, passed underneath the Meteor, and climbed, turning slightly to the right. The Vampire's starboard rudder, fin and elevator struck the Meteor's port engine nacelle nosing which separated from the aircraft and fell clear. The Vampire's starboard rudder detached and fell clear. After the collision, the Vampire pitched-up and the two crew ejected successfully. The Meteor, which was not fitted with ejection seats, struck the ground shortly after the mid-air collision and the two-crew members were killed. Both aircraft were destroyed. The investigation established that, although the Meteor pilot's flying of the barrel roll may have made maintaining formation difficult, the Vampire pilot could have avoided the subsequent collision by turning away to the left. (David Oliver)

2 JUNE 2001: DE HAVILLAND 112 VENOM (DE HAVILLAND COLLECTION, BIGGIN HILL, UNITED KINGDOM)

The aircraft was being flown from Bournemouth, Dorset to Biggin Hill, Kent as the number three aircraft in a three-ship formation positioning for the annual Biggin Hill Air Fair. On arrival at Biggin Hill the three aircraft carried out a 'run-in and break' manoeuvre from line astern formation for a landing on Runway 21. On the downwind leg the pilot carried out the pre-landing checks, which, included amongst other things, the lowering of the undercarriage, selecting one-third flap and a check of the brake pressure. After lowering the flap, the pilot checked the flap position indicator and noticed that the flap was at more than the one third setting. He then raised the flap to the correct setting and continued the approach.

As he entered the turn to final approach, the pilot lowered full flap and concentrated on achieving an even spacing between the three aircraft whilst avoiding the slipstream of the two aircraft ahead. He became conscious that the spacing between the lead aircraft and the number two was less than between his own aircraft and the number two and applied power to reduce his spacing on the aircraft ahead. He checked the undercarriage indications and, although he had some difficulty seeing the indications in the prevailing light conditions, he convinced himself that the undercarriage was down and called "FINALS THREE GREENS" on the tower frequency.

The pilot then carried out a normal flare and touchdown with the aircraft landing on its belly. Although there was some nose vibration in the latter stages of the landing run, the pilot reported that he did not initially realise that he had landed with the wheels up until advised by ATC. When the aircraft came to a halt, the pilot shut down the aircraft systems, safetied the ejection seat and egressed, uninjured.

During his first flight on the previous day, the pilot had noted that the undercarriage position indicator lights were quite dim and difficult to discern being positioned as they were to the lower left of the instrument panel. The 69-year-old pilot was highly experienced with a total of 5,574 hours of which 242 were on type, but he had only flown 10 hours in the last 90 days and 6 hours in the last 28-day period. Although the pilot had over 200 hours flying experience on type, this was only his second flight on type in eight years and only his second flight in this specific aircraft, G-GONE.

In his report the pilot considered that three factors contributed to his failure to lower the undercarriage. Firstly, the undercarriage and flap levers are located in close proximity to each other and are of similar design. Although he thought he was lowering the undercarriage during the pre-landing checks, he believes that he actually lowered the flap instead. When he subsequently checked the flap position indicator after completing the checks and discovered more than the desired flap setting, he failed to associate the excessive flap with a failure to lower the undercarriage lever. Secondly, the location of the undercarriage position indicator in the cockpit and the intensity of the lights sometimes made the undercarriage position difficult to discern. Lastly, the focussed concentration required to carry out a streamer-landing may have distracted him. (AAIB Bulletin No: 9/2001, Ref: EW/G2001/06/01)

The question of continuation training begs asking since all the regulations, certificates and experience are meaningless unless the pilot is current on type in airshow flying. The oversight by the pilot regarding flap and undercarriage selection are well documented deficiencies in the Vampire's ergonomic design and was usually taught to pilots as 'traps' to guard against during their basic conversion to type. Was this an accident just looking for a place to happen?

After exhausting all possible alternatives to extend the mechanically locked right main wheel, the only available option was to land with one main wheel retracted and one extended. (SAAF Museum)

6 MAY 2001: MUSTANG P-51D (SAAF MUSEUM, AFB WATERKLOOF, SOUTH AFRICA)

An annual air force Memorial Day flypast included a formation of one P-51D Mustang and two T-6 Harvards. On downwind for landing, only the left main undercarriage of the Mustang lowered. Upon trying to recycle, the pilot discovered that the undercarriage lever was stuck (hydraulic lock) and could not be moved. In the physical effort to recycle the undercarriage, the pilot actually broke the undercarriage lever. After all other efforts to lower the undercarriage had failed, a landing on the grass with the left main gear extended and the right main gear retracted, was executed. There were no injuries or collateral damage but extensive work was required to repair the structural damage to the aircraft.

The right main undercarriage up-lock latch activation rod had disconnected and it was thus physically impossible to disengage the up-lock in-flight. The aircraft had been re-assembled over a period of six years and the remote placement of the up-lock mechanism was such (impossible to reach it) that the cockpit was installed before the dual check was carried out. The I-bolt connecting the rod and lock was not properly screwed into the rod and with time (repeated cycling), disengaged due to wear. Once again, following the write-off of the SAAF Museum's only airworthy Spitfire, South African media and aviation magazines covered the emotive and contentious issue of flying 'one off' vintage warbirds at displays and flypasts.

15 APRIL 2001: H-4 CO-AX COPTER (SUN 'N FUN, USA)

The 'pilot' fired up each of the four tiny little two-stroke engines, one at a time, using their electric starters - no pull-cords for this thing. Without further ado, he climbed on, strapped in and revved it up without the need to warm it up much - a thousand angry hornets? There were lots of spectators around and it obviously drew a large crowd. The H-4 pilot seemed to have a pretty good command of his little ship. Lifting-off to a high hover, estimated at 20 feet or so, he moved up and down the flight line in a fairly stable and controllable manner.

After a short time, the pilot returned to 'show-centre' just south of the tower, but he came to a lower hover this time. His camera crew that had been getting reaction shots of the crowd and were now busy setting up their tripod to film him, but they were not pointing the camera in his direction. The pilot was looking to the left, perhaps for his crew when suddenly, for no apparent reason, he pushed forward rather sharply on the T-bar control stick which put the aircraft in a rather extreme nose-up attitude. A spectator remarked: "He's too low to be doing that!" Sure enough, as expected, the craft started to settle.

In response, the pilot reacted by getting into a classic case of pilot induced pitching oscillations (PIO). During the second or third excursion, the rear support stanchions hit the ground and collapsed. Everyone thought it was all over at that point, but the pilot must have applied full throttle because the craft recovered and staggered, wobbling back into the air, but not for long. The pilot, over-saturated with high information rate cues, just couldn't keep or get the craft under control and it quickly rolled beyond the point-of-no-return and fell over on its side. By now, the spectators were ducking for cover with parts and pieces flying around, thankfully in the opposite direction from the crowd.

People rushed to the pilot's aid and as he stood up, the crowd, quite ironically, erupted in applause. The requirement for such a device, strap-on helicopter, rocket backpack, etc, is a strange one. However much we would all like to fly like Superman, one simply cannot envision CEO's in their three-piece Armani suits zipping off to work in their Gen H-4's, yet people persevere in trying to perfect them. (Internet)

10 APRIL 2001: TUTOR CL-114 (RCAF, *SNOWBIRDS* , BRITISH COLUMBIA, CANADA)

Canada's *Snowbirds* demonstration team suspended all flights while investigators evaluated why one of the team's Canadair CT-114 Tutor trainers suffered a collapse of part of its right main undercarriage during a practice formation landing. The pilot escaped injury as he landed the aircraft. The team was nearing the end of its annual two-week practice session at Comox on Vancouver Island in British Columbia before beginning the 2001 airshow season during which the *Snowbirds* were slated to fly in sixty-seven shows at forty-three different sites across North America.

The last time a Snowbird suffered a landing gear collapse was in 1999, when a hard landing collapsed a Tutor's nose gear. In that instance, a mechanical fault was ruled out and focus was shifted to unit procedures, including the relationship between first-year pilots and veteran 'counterparts' assigned to each new *Snowbird*.

The aircraft was No.5 of a nine-plane formation landing after an on-field airshow practice. During touchdown on runway 29, the No.5 aircraft was in the "slot" position of the nine-ship for the landing, right at the back of the formation. The aircraft bounced on landing, becoming airborne again but then quickly stalled back onto the runway, heavily. The right-hand main undercarriage was forced upwards through the top surface of the right wing and collapsed while the nose wheel also partially collapsed. The aircraft slid along the runway on the right-hand smoke tank, left-hand main undercarriage and partially collapsed nose wheel before coming to a stop. The pilot shut the engine down, turned off electrical equipment and egressed from the aircraft. The on-scene-command-emergency-response (OSCER) vehicle and fire fighting vehicles arrived within approximately two minutes and sprayed foam on the underside of the aircraft. An ambulance arrived at the accident site after approximately eight minutes and took the pilot to the 19 Wing hospital.

The 15 Wing Commander initially terminated nine-ship formation landings until a formal risk assessment to evaluate the risk versus benefit of a '9' or '7' and '2' aircraft formation landing was completed. Particularly emphasis was placed on including escape lanes in the event of a go-around. (RCAF Directorate of Flight Safety)

16 FEBRUARY 2001: A4-SKYHAWK (RNZAF, NOWRA, AUSTRALIA)

Chronic pilot fatigue and system's failures were blamed for the Skyhawk crash which claimed the life of Squadron Leader Murray Neilson, aged 37, Commanding Officer No 2 Squadron, Royal New Zealand Air Force. He crashed while practicing an aerobatic manoeuvre over Nowra in Australia in preparation for the upcoming Avalon Airshow. The Air Force Court of Inquiry found that there were no technical or mechanical problems with the Skyhawk. It did however conclude that Squadron Leader Neilson was suffering from chronic fatigue and was distracted in flight, leading him to perform a barrel roll from too low a height. In mitigation, it also found that he was trying to do too much with too few resources at squadron level.

Squadron Leader Neilson was, however, credited with saving the life of his wingman by warning him of the impending catastrophe. The manoeuvre involved the two aircraft flying one in front of the other, simulating an aerial refuelling profile. He was the lead in a 'plugged-bell roll' manoeuvre at the time and he failed to recover from the pullout of the barrel roll. The aircraft burst into flames on impact in a wooded area adjacent to HMAS Albatross, Australia.

17 DECEMBER 2000: T-34 MENTOR (ISTANBUL, TURKEY)

A T-34 Mentor crashed during an airshow in the Korfez township of north-western Kocaeli province near Istanbul, Turkey, killing the pilot and a passenger/photographer aboard the aircraft. The T-34 Mentor, an earlier generation two-seat trainer, crashed onto railway tracks, injuring two spectators amongst the 6,000 people watching a car rally near Izmit city, 100 kilometres (62 miles) east of Istanbul. The car rally was postponed.

Pilot A. Aselim Kayacýk and Pilot Faruk Utku from Istanbul Civil Aviation Club, took off with T-34A (TC-IHL) at Samandýra Aerodrome at 14.30 loca l time. Another T-34 (TC-IHK) departed from the same aerodrome, joined up in formation and both aircraft then flew to the Korfez region. After the formation made two passes over the Korfez Car Rally Track at 500 feet and during the third fly past, one of the aircraft (TC-IHL) pulled up nearly vertically and at the apex of the pitch-up point, commenced what appeared to be a stall-turn to the right. The aircraft entered a spin from which the pilots could not recover the aircraft and then impacted the ground at a high angle and very close the spectators alongside the railway line. Both pilots were killed and two women working in a garden outside the racetrack area were injured, unfortunately one died the following day.

18 AUGUST 2000: AERO L-29 DEPLHIN (EASTBOURNE, UK)

Ten policemen tried to find the remains of the L-29 Delfin jet which was piloted by former *Red Arrows* pilot Ted Girdler, 63, from Kent. Ted Girdler was a highly experienced display pilot with a total of 18,222 hours (of which 235 were on type) and in the last 90 days had flown 146 hours and the last 28 days, 46 hours. He was flying the aircraft 800m off the coast at Eastbourne during the annual Airbourne 2000 show when it crashed. One of Mr Girdler's sons was among the thousands of horrified onlookers who witnessed the accident.

The policeman who led the search, said there had not been any signs of wreckage. "It seems that the impact was so catastrophic that there may be no large sections of the plane left," he said, "but we still hope to be able to salvage parts of the cockpit and wings." The divers could only search for two hours because the Airbourne 2000 airshow resumed flying displays over the sea. "We were unable to work below the airshow because of public safety," he said. Later, after pinpointing the wreckage, a strong tide delayed recovery attempts before the wreckage was eventually recovered. Event display co-ordinator Jim Maitland said Mr Girdler was very highly thought of. "He was very experienced and was responsible for checking out the pilots on this particular aircraft," he said, "he will be sorely missed by everyone who knew him in the display world."

Air accident investigators were puzzled why Mr Girdler was unable to pull up during what should have been a "low risk diving roll". No attempt at ejection was made by Mr Girdler and no Mayday call was made. The aircraft was fitted with a modified MiG-15 ejection seat system, activated by pulling a lever attached to the right armrest, however, the force required to initiate ejection was considered excessive at 30 to 40 kg. Pilots flying the aircraft considered the system unsuitable for use below 1,000 feet agl and 90 kts. The lifeboatman who recovered the pilot's body from the water, said it was a miracle that no one else was killed. "It was 200 or 300 yards from three of the safety boats which were patrolling the area and we are all lucky to be alive," he said. "He was coming in at probably an angle of 45º and tried to pull up but belly-flopped into the sea. He just didn't have enough space."

Investigators found no evidence of failure in the pilot's health, aircraft integrity or observance of limitations imposed by the authorities. Analysis of one of the many videos taken of the catastrophe revealed that the first half of a half Cuban-eight, with one and a half aileron rolls at a 45º-dive angle, was normal. The second half appeared normal but during the entry to the full descending aileron roll, the nose of the aircraft pitched up slightly causing the aircraft to turn off the intended roll axis. Then, when the aircraft rolled through the inverted, the nosed dropped to a near vertical position and a high rate of descent developed. From this very steep nose down position, the pilot rolled the wings level and then attempted to pull out of the dive. Condensation trails could be seen from the wing tips as the wings were generating maximum lift, but there was insufficient height in which to effect recovery. The impact with the water was in a 15° nose down attitude with 40º of left bank. Nearby rescue boats were over the site of the impact within thirty seconds and located the pilot but he had suffered fatal injuries.

The pilot was known to have been meticulous regarding achieving predetermined 'gate' heights before commencing any manoeuvre. Video recordings showed that the time to pull up into the final half of the Cuban from level flight was the same as on the other occasions so unless the speed was considerably less, a similar height at the top should have been attained. Both of these factors suggest that the pilot had sufficient height to carry out the manoeuvre he was attempting.

The AAIB discussion stated that it was usual practice to perform the half roll from the top of the loop, hold the wings level attitude briefly, pitch the nose up positively by 10º to 15º, check that the 'gate' height was 1,500 ft and then to enter the full aileron roll. On this occasion, however, there was no hesitation before the full roll and no pitch-up seen until the roll started. This deviation from his normal practice may indicate that there was a problem. A temporary loss of reference, disorientation, disability or loose article in the cockpit, remained a probability and the subsequent steep nose-down attitude resulted in an excessive height loss, which proved fatal. Whatever had occurred, the pilot was nevertheless able to carry out a recovery from the dive to a wings level attitude but with insufficient height to affect the recovery pullout, the aircraft crashed into the sea.

18 JUNE 2000: GRUMMAN F-14 (USN, WILLOW GROVE, PENNSYLVANIA, USA)

The pilot and radar intercept officer aboard a Grumman F-14 'Tomcat' died when their F-14 crashed as horrified airshow spectators looked on. The aircraft was the second-to-last performance at the annual Willow Grove 2000 "Sounds of Freedom" airshow. The fighter was based at Oceana Naval Air Station in Virginia Beach, Va. The Navy identified the pilot as Lt. William Joseph Dey, 30, of Hightstown, N. J., and Radar Intercept Officer Lt. David Erick Bergstrom, 31, of Annandale, Va. Both men had more than 1,000 hours on the F-14; Dey was an instructor pilot in the VF-101 fighter squadron.

The 'Tomcat' was demonstrating a landing 'wave-off' manoeuvre which was essentially a go-around from the landing approach; approaching at slow speed to simulate a landing and then circling for another attempt as if 'waved-off' from the first. Having selected go-around power, the aircraft rolled inverted and then appeared to regain stable flight transiently for a couple of seconds, rolled right side up then rolled into a 90º bank nose-level turn and started pulling hard. The nose pitched down sharply while still in a steep bank before the aircraft rolled to a nearly wings-level attitude but with insufficient height to effect a safe pullout.

A witness in the crowd said that he was watching as the aircraft turned, faltered, and sank toward the trees. "When he got below the trees, you could tell he was in trouble. It looked like it fell out of the air," he said. "It was only a second, and then there was smoke and a huge fireball." Although the aircraft sent flames and smoke billowing from a wooded area at the end of the runway, no public or spectator injuries were reported and no structures were damaged. Three emergency personnel, however, including a military fire-fighter, were treated for injuries at the crash scene.

An aviation photographer at the airshow reported that it may be hard to believe, but he was only about 200 feet from the crash site. From what he saw, the F-14 lost its left engine while directly overhead, the pilot had selected full throttle on the right engine going into afterburner but by this time, he was already hitting trees and then nosed in. "I have to tell you that this is one the most upsetting things I have witnessed in my sixteen years of aviation photography," he said. "I know he was fighting the jet from hitting houses. Another idea of how close he was to me, my wife and brother-in-law were waving at the back seater as they went directly overhead inverted. But through my lens I saw the back seater with both hands on the canopy and looking down at us. I feel so bad for the families of the crew".

Another eyewitness reported that: "It appeared to me at first the he didn't flame-out but rather, lost control. "Before that, and after he lifted his gear, he banked to the right and went inverted, right there I knew he was gone. Apparently going inverted was a part of the routine." And still another witness reported: "The pilot approached the runway for a simulated landing and it looked fine," he said, "the jet was then waved-off as planned and turned to the right. At that point, the plane appeared to lose control and crashed into a wooded field near a residential area". "The jet dove into a grove of trees, you could see a huge fireball and smoke", he said. "I took a picture of it as it came over me and two seconds later, it crashed. It was unbelievable."

The crash forced some residents from their homes and the Red Cross set up a temporary shelter for those residents while authorities investigated the crash. Comment from one of the shocked spectators: "Hard to believe that the high cost in lives and aircraft is worth the 'entertainment' value of such military taxpayer funded airshows". It was the second fatal crash of a military aircraft at an airshow in three months. On 19 March 2001, an Air Force F-16 fighter crashed while performing manoeuvres as part of an airshow near Kingsville Naval Air Station in Texas, killing the pilot.

In Russia on 17 July 2001, a similar accident occurred in which a Russian navy pilot died after his Su-33 fighter jet crashed at an airshow marking Navy Aviation Day. Major General Timur Apakidze, deputy commander of Navy Aviation, died on his way to hospital, fifteen minutes after being dragged from the wreckage of the Su-33 near the north western city of Pskov. Apakidze, held the Hero of Russia order, the country's highest honour for his achievements in aviation. The aircraft reportedly lost altitude after performing a series of aerobatics and was setting up a simulated carrier landing when a high rate of descent ended in impact with the ground, the Interfax news agency correspondent at the air show reported.

3 JUNE 2000: AERO L-39 ALBATROSS (SLOVAK AIR FORCE *BIELE ALBATROSY* SLOVAKIA)

The Slovak *Biele Albatrosy* (White Albatross) team lost their number 3 pilot, Major Luboš Novák, in an accident during a performance at Sliac Military airport in Slovakia.

27 MAY 2000: MUDRY CAP 10 (*"FRENCH CONNECTION"* TEAM, FLORIDA, USA)

The civilian " *French Connection"* team of husband and wife Daniel Heligoin (69 years) and Montaine Mallet (52 years) were both tragically killed as a result of a mid-air collision between their two Mudry CAP 10 aircraft while filming a promotional tape for their airshow act. The two Avions Mudry CAP-10B's, registered to and operated by "French Connection Airshows, Inc." as a Title 14 CFR Part 91 formation airshow practice flight, crashed at the Flagler County Airport, Bunnell, Florida. Visual meteorological conditions prevailed. Both aircraft were destroyed and the CFI-rated lead pilot and commercially-rated wingman, sustained fatal injuries.

The formation flight departed about fifteen minutes before the accident. According to eyewitnesses and examination of a video-tape of the flight, the team had performed a formation hammerhead stall that terminated with the wingman rolling 180º while the team was in their nose-down vertical recovery from the hammer-head stall. Going essentially belly-to-belly, an immediate pull-out resulted in a formation split into flight paths 180º apart. The accident occurred on the second attempt of the same manoeuvre after the wingman accidentally rolled into the formation.

Heligoin and Mallet had both completed the hammerhead portion of their routine and started on the downline when Mallet's right wing hit the trailing edge of Heligoin's left wing at a height of approximately 500 ft. In reviewing the video tape, it appeared that Heligoin drifted into Mallet's flight path and since Heligoin was lower than Mallet, Mallet may have been unable to see Heligoin. There was no apparent attempt to bail out and both aircraft impacted the ground nose first, a couple of hundred feet apart. There was no fire and no one on the ground was injured. Another witness reported that she saw the wing of one aircraft hit the other. "At first I just thought it was some trick where one aircraft goes around the other," she said. "There was no explosion, just pieces." (NTSB ID: MIA00FA172A).

Heligoin started performing in the United States in the CAP 10 in 1974 to market the aircraft for Avions Mudry of France, and teamed up with Mallet shortly thereafter. The *French Connection* gained great repute for their 'mirror image' manoeuvre in which one aircraft would fly straight and level with the other aircraft inverted directly above it, canopy to canopy. Their dual routine was considered a headline act. Heligoin and Mallet received the "Bill Barber Award For

Showmanship" in 1987, sponsored by World Airshow News and served on the award's selection committee ever since. They were also past recipients of the "Art Scholl Memorial Showmanship Award."

26 APRIL 2000: EDGE 360 ("WILD BILL'S WILD RIDE", LOUISIANNA, USA)

"Wild Bill" Marcellus suffered a 'too-close encounter' with the ground at the Barksdale AFB Base, Louisiana Airshow on 26 April 2001. Marcellus was nearing the end of a high-energy routine when he hit the ground with enough force to bend the aircraft's undercarriage. Flying at nearly 200 mph about 30 feet off the ground, a bird apparently flew into the Edge 360's propeller. The aircraft hit the grass field and bounced back into the air before Marcellus was able to set it down. Marcellus was hospitalised with two cracked vertebrae but was expected to be back in the cockpit - the Edge 360, though, would in all probability never fly again. (Avweb)

15 APRIL 2000: SPITFIRE MK IX (SAAF MUSEUM, AFB SWARTKOPS, SOUTH AFRICA)

Engine failure due a combination of a slipped supercharger clutch plate and a hardened carburettor diaphragm, was enough to force the only airworthy Spitfire of the South African Air Force Museum to crash short of the runway at AFB Swartkops, South Africa. Flying in a loose formation with another civilian owned Spitfire for the first high-speed fly past, station was maintained until the lead aircraft commenced with a wingover to the right for a steep turn away from the crowd; the aircraft only got back into position at 'show centre' as the leader called a turn to the left. An eyewitnesses on the ground, an ex Spitfire pilot, noticed black smoke intermittently appearing from the right exhaust but he was not near a radio and started to run towards the control tower 120 metres away.

Half way through the turn, the wingman was again struggling to keep up and required more than usual throttle to maintain 8-psi boost. The exhausts spat out increasing lengths of black smoke (indicative of an over rich mixture) and as the formation passed crowd centre for the second time, they pulled up for the wingover to the right. The wingman once again fell behind and as the formation passed through 600 - 700 feet agl, the first indication of an impending engine failure was the sudden loss of power manifested by a rapid nose drop below the horizon and the pull-away by the lead aircraft. The pilot, Lt Col Neill Thomas managed to get the aircraft turned around to land on the active runway, but not before expending valuable time in having to manually pump the undercarriage down. The aircraft had only been fitted with a manual emergency undercarriage extension capability.

Landing short of the runway, the aircraft impacted the ground tail first with a nose-up attitude of approximately 18°. The tail hit a large rock before it broke off, slewing the aircraft slightly to the right. At this point the nose impacted the eight-foot high concrete security wall, collapsing the wall as the aircraft burst through the wall coming to a rest 45 feet from the point of initial impact, the pilot suffered minor injuries only. Needless to say, the criticism of the SAAF Museum by the veterans and general public for flying rare, airworthy museum aircraft, was vociferous. (This accident is addressed in more detail in Chapter 4)

19 MARCH 2000: USAF F-16 (KINGSVILLE NAVAL STATION, TEXAS, USA)

Six minutes into the display, the pilot of an F-16 had insufficient altitude and excessive airspeed which prevented him from completing a 'Split-S' during an aerial demonstration at the Kingsville Naval Air Station, Texas, Airshow 2000. The pilot, Maj. Brison Phillips, 35, a member of the 78th Fighter Squadron and the commander of the 9th Air Force F-16 Demonstration Team of Shaw Air Force Base, S.C., was killed in the accident. According to the accident report, Maj Phillips was a highly experienced pilot with more than 1,898 hours on the F-16 and 130 combat missions. He was highly qualified and an excellent pilot and instructor who had demonstrated exceptional maturity and professionalism. He was current and qualified in all areas of the display mission.

The aircraft exploded, scattering debris for a half-mile in a field about six miles north of the naval base with no collateral damage to infrastructure. A Corpus Christi resident saw the aircraft hit the ground. "There was a bright, red and orange fireball," he said. "You could hear it and feel the shock of the concussion, it felt like someone hitting you in the chest." The rest of the airshow, which was to include a performance by the Navy's *Blue Angels*, was cancelled.

Accident investigators concluded that the pilot focused too much attention on ground references, leading him to begin the 'Split-S' from an altitude at which it could not be safely completed. Strong winds and a complex and unfamiliar ground environment were likely contributory factors, according to the Accident Investigation Board report. Strong winds required the pilot to adjust parameters to prevent being shifted away from the show line and investigators believed it may have been difficult for him to remain oriented to the show line at the Kingsville airfield with its multiple crossing runways. These factors contributed to the pilot's intense focus on ground references and his failure to adequately monitor his altitude before beginning the Split-S, investigating officials concluded.

9 JANUARY 2000: PITTS S-1 (UPLAND, LOS ANGELES, CALIFORNIA, USA)

A crash at a California airshow killed the pilot of a Pitts S-1 aerobatic biplane, Mark Madden of La Mesa, California. The aircraft crashed and exploded during the Pomona Valley Air Fair in Upland, about 50 miles east of Los Angeles as more than three thousand spectators had arrived to watch skydivers, aerobatic performers, helicopters and World War II-era aircraft celebrate the show's 25th anniversary. This was the first accident to occur during the twenty-five years of the airshow, an event sponsored by the Pomona Valley Pilots Association and the Experimental Aircraft Association.

The Pitts was doing a series of snap rolls on a 45º downline, recovered wings level, but hit the ground and exploded about one-half mile north of the airport. No one on the ground was injured when the aircraft went down. This was one of many accidents involving downline multiple snaps; there are several in NTSB reports and this accident was similar to an accident a few years ago involving double snaps into a landing. Unfortunately, the NTSB reports on most of these categories of accidents are ineffectual to learn from i.e. "Pilot failed to recover", etc. No analysis is presented and as a teaching tool, is not as insightful as they should be.

So, what is it about a downline snap that gets away from some highly experienced pilots? Well, the amount of energy lost is highly dependent on small changes in technique and unfortunately pilots let their energy budget get to close to the edge during an airshow.

28 OCTOBER 1999: BOEING F/A-18 (USN *BLUE ANGELS*, MOODY AFB, USA)

In what was the precision flying team's first fatality in more than fourteen years, the *Blue Angels* suffered a tragic accident which claimed the lives of two of their pilots during a training flight on 28 October 1999. An F/A-18 from the Navy's *Blue Angels* precision flying team crashed while making a routine pre-show survey flight and planning manoeuvres in preparation for the airshow over the coming weekend. The *Blue Angels* were scheduled to perform two shows that weekend during the Moody Air Force Base Community Appreciation Day, but the airshow was cancelled because of the crash.

The $32 million F/A-18 hit a stand of pines on a farm just north of Moody Air Force Base. Cmdr. Patrick Driscoll, flight leader of the *Blue Angels*, identified the dead pilots as Lt. Cmdr. Kieron O'Connor, 35, of Burtonsville, Md., and Lt. Kevin Colling, 32, of Castle Rock, Colo. "I had the privilege of flying with both these pilots in the fleet," Driscoll said. "They were two of the best naval aviators I know. This is a tragic loss to the families, to the *Blue Angels* and the U.S. Navy."

Driscoll said the aircraft were not flying in close formation but were circling, practicing positioning and run-in procedures as the pilots familiarized themselves with the terrain; they were in the vicinity of each other, but not as close as they usually fly when flying displays. The crash came during a low turn over a field of pine trees while O'Connor and Colling were scouting the physical landmarks that would guide their performance. After the mishap, the team cancelled its appearances at Moody AFB and at the 'Jacksonville Air and Sea Spectacular', which took place the following weekend. The team did, however, perform at its final scheduled show of the 1999 season, a late November homecoming show in Pensacola.

A witness of Douglas said she saw the team fly over a grocery store where she was shopping. "They came over in a beautiful formation. I think there were six of them," she said. "It was probably a half an hour later that we saw the smoke. I didn't hear a crash or anything.

Someone said they must be burning garbage, then a little while later the fire trucks came by." Witnesses saw a fireball when the aircraft struck the ground in woodland near Valdosta but there were no reports of parachutes being seen.

A 55-year-old farmer was eating lunch at his home about a half-mile from the crash site when he heard a noise he thought might have been a sonic boom. "I thought maybe one got a little fast and went through the sound barrier," he said. "About five or ten minutes later, I went out back and smelled smoke, it had set the woods on fire." Authorities closed off the crash site, keeping reporters and the public about two-thirds of a mile away.

Brig. Gen. Gene Renuart, commander of the 347th Wing at Moody said: "This is the Navy's premier flying team, a team that performs to the amazement and pleasure of crowds all over the United States, and you can be sure the Navy will do whatever it can to make sure that this team is at the very top of its ability to fly." Renuart said that even the most routine flights have an element of risk. "Anytime you put an aircraft in the air, it's hazardous," he said. The Navy had recently announced that fiscal 1999, which had ended the previous month, was one of its safest flight years ever with only nine 'Class A' accidents and six fatalities. Class A accidents involve either a fatality, the loss of an aircraft or more than $1 million in damages.

In 1992, more than one million people watched the *Blue Angel's* performances during a 30-day European deployment to Sweden, Finland, Russia, Romania, Bulgaria, Italy, Britain and Spain. For the year 1999, the team had sixty-eight airshows scheduled at thirty-six locations in the United States and Canada; an estimated 10 to 15 million people watch the team each year.

The *Blue Angels* fly to numerous locations world-wide to perform each year and flew their first flight demonstration in June 1946, less than a year after Adm. Chester W. Nimitz, then the chief of naval operations, ordered the group's formation to keep the public interested in naval aviation. Since the *Blue Angels* were formed in 1946, the group had performed for more than 322 million people. Including the current deaths, 23 *Blue Angels* pilots had been killed in airshows or during airshow training.

O'Connor, who was riding in the back of the jet, joined the *Blue Angels* in September 1998 and as an active team flyer a year later. O'Conner, had extensive flying experience with more than 2,000 flight hours and 295 carrier landings and was completing his first year as a *Blue Angel*. Lt. Colling was finishing his first month with the squadron and was scheduled to be one of the new pilots the following year. Navy officials confirmed that O'Connor was piloting the aircraft which was not flying in tight formation or executing any of the squadron's manoeuvres at the time, a Navy spokesmen said, "he was in 'loose cruise' formation at the time of the crash. The aircraft was reportedly the No.7 aircraft, which was the *Blue Angels*' only two-seat version of the F/A-18 Hornet.

03 OCTOBER 1999: ORACLE TURBO-RAVEN (CALIFORNIA INTERNATIONAL AIRSHOW, USA)

Wayne Handley crashed in his Turbo Raven at the California International Airshow in Salinas; he had just begun his performance, a loop on take-off back to a landing when his Turbo Raven hit hard, belly first, on the tarmac, breaking-off the aircraft's landing gear and causing significant damage to the aircraft.

The pilot was performing a one-minute aerial sequence, which began and literally ended at the same spot on the runway. The propeller had a Beta range operating capability and was reversible to produce zero or negative thrust. Near the completion of the manoeuvre, the pilot established a descent angle of approximately 50º to 60º. After going into Beta reverse range, the pilot brought the propeller into flight idle as he descended through about 800 feet agl. The pilot said he moved the thrust lever forward to achieve 85 to 90 knots but the engine did not spool up; he believed it might have flamed out. He maintained a nose down attitude with airspeed on the verge of a stall and was able to briefly maintain a minimum sink rate, which increased just prior to impact.

Examination of the engine revealed signatures consistent with operation in the mid to high power range at impact and there were no indications of any anomalies or discrepancies that would have precluded normal engine operation. Examination of the propeller revealed internal witness marks consistent with the blades being in the normal operating range at the time of impact. The

National Transportation Safety Board determined the probable cause(s) of this accident as the pilot's failure to maintain an adequate airspeed while manoeuvring, which led to a stall/mush condition.

A spectator at the show remarked: "I just saw him fly at Stockton - I believe he used all of Newton's laws of physics during this demonstration. It was awesome to see a full size plane do a torque roll, then gradually descend perfectly on its tail, doing at least three or four aileron turns on the way down". Wayne Handley was a former Naval Aviator, aerobatic champion, 'ag' pilot and aerobatic instructor and in his 43-year aviation career had amassed a phenomenal 25,000 hours of manoeuvring time. His aerobatic ability had earned him the title of California Unlimited Aerobatic Champion, not once, but three times. In 1989 he became the world record holder for inverted flat spins, having completed 67 consecutive turns and in April 1999 flying a G-202, he increased the world record for inverted flat spins to a phenomenal 78 turns. In 1996 he was presented the Bill Barber Award for Showmanship and in 1997 the Art Scholl Memorial Showmanship Award, two of the most prestigious awards in the airshow industry.

Rescue personnel from the show responded to the accident quickly and within a few minutes reported that Handley was conscious and moving in the cockpit. He was taken to the Salinas Memorial Hospital where he underwent exploratory surgery to determine the exact nature of his injuries. According to reliable reports, Handley suffered two cracked back vertebrae and severe pain in his lower back, but fortunately no permanent spinal cord injuries.

The Oracle Turbo Raven, powered by a 750 HP Pratt & Whitney PT6A-25C, was the first airshow aircraft to have a positive thrust to weight ratio and at a performance weight of 1,900 pounds, and with 2,800 pounds of thrust, the Turbo Raven could climb straight up, stop in the vertical, and then accelerate straight up again. The Oracle Turbo Raven, due to its extremely high Shaft Horsepower/Weight ratio, is reportedly able to power itself out of a flat spin without lowering the nose below the horizon.

01 OCTOBER 1999: BEECH T-34 (*LIMA LIMA FLYING SQUADRON* AEROBATIC TEAM, ILLINOIS, USA)

Two aircraft of the *Lima-Lima* flight team collided above rural Oswego, Illinois, USA during a formation practice session killing the pilot, Keith Evans in the accident. The Beech D-45 was destroyed on impact with the ground after a midair collision with a Beech T-34 during a practice manoeuvre. *Lima Lima* is the only six-ship civilian aerobatic team in the world.

Both aircraft departed in sequence from a 6-ship delta formation to perform a manoeuvre called a 'pop-top' break. The 'pop-top' break involved each aircraft splitting from the formation in sequence by entering a climbing 180º turn to follow the lead aircraft in trail. A videotape of the accident flight showed a delayed entry into the turn by the D-45 relative to the T-34's entry into the manoeuvre. The pilot of the T-34 stated that he did not see the D-45 prior to the midair collision.

The National Transportation Safety Board determined the probable cause(s) of this accident as the visual lookout not obtained by the pilot of the Beech T-34 due to the narrow visual field of the human eye which is approximately 10º-15º. In addition, inadequate procedures by the *Lima-Lima Flying Squadron* to deal with 'lost visual contact' between formation members and the delayed entry into the manoeuvre by the pilot of the Beech D-45, were listed as contributing factors. (NTSB Identification: CHI00FA003A)

19 SEPTEMBER 1999: HOMEBUILT P-51 (RENO AIR RACES, USA)

The Reno Air Races experienced every man's dread in the Unlimited Race 3A when Race 38, Miss Ashley II, flown by former furniture tycoon Gary Levitz, lost a wing in the first turn past the start-finish line and disappeared over the hill into Lemon Valley. The race continued and Tiger Destefani lead all six laps to win over Bruce Lockwood in Dago Red. The pilot did not survive the accident and no other injuries occurred to the crowd of nearly 30,000 that stood around in shocked disbelief at what they had seen.

Two eye witnesses who ran a perpetual yard sale and flea market on the south side of the Lemon Valley reported that the left wing and parts of the tail were separated from the home built P-51 before it hit the ground in a huge fireball, less than a mile from the crash site of the last two race aircraft crashes, The *Red Baron* RB-51 in 1979 and *Precious Metal* , a P-51 flown by one of the Whittington brothers in the early 1990's.

Levitz's aircraft hit the ground, slid across a roadway, went through a barn and knocked the back end from a truck camper being worked on by a local resident who miraculously, was not injured. The right wing fluttered upward and landed among houses while the remains of the fuselage and engine went about two blocks further on and came to rest a few feet from a manufactured home, the residents of which proceeded out and sprayed water on the wreckage with a garden hose. Reno race officials cancelled the performance of the USAF *Thunderbirds* Aerobatic Team.

12 SEPTEMBER 1999: CESSNA L-19 BIRDDOG AND CESSNA O-2 SKYMASTER (MASSACHUSETTS, USA)

A Cessna L-19 Birddog and a Cessna O-2 Skymaster collided in mid-air during an airshow in North Hampton, Massachusetts, USA, killing both pilots.

08 AUGUST 1999: SAAB JAS 39 GRIPEN (SWEDISH AIR FORCE, STOCKHOLM, SWEDEN)

A SAAB JAS 39 'Gripen' crashed on Sunday, 8 August 1999 during an air display over central Stockholm. The aircraft was flying straight and level at low altitude and moderate airspeed when it suddenly began a gentle rocking motion in roll, then the nose pitched up rapidly, passing the vertical in a manoeuvre resembling 'Pugachev's Cobra'. When the aircraft had pitched up well past the vertical to approximately 120º, the pilot ejected and landed unhurt while the now pilotless aircraft, after some further transient manoeuvres, settled into a vertical descent in about a level attitude.

The aircraft did not break up in the air and struck a small hill on an island (Laangholmen), exploding on impact, only tens of metres from a major bridge packed with spectators. Miraculously no one on the ground was killed and there was no significant collateral damage on the ground.. The pilot was unhurt but three people suffered minor burns, while one sprained an ankle running away from the crash scene.

The JAS39 is a statically unstable aircraft controlled through a "fly-by-wire" (FBW) control system with triple redundant computers. The FBW system was immediately suspected as the reason for the crash since the behaviour of the aircraft was typically that which would be expected after a major failure of the FBW system. A spectator listening on the radio frequency used by the aircraft during the display, claimed that immediately before control was lost, the pilot reported that a circuit breaker had tripped. The aircraft that crashed was the first one to be delivered to the Swedish Air Force and was flown by the same SAAB display pilot that flew the first accident aircraft. (Lars-Henrik Eriksson, Swedish Institute of Computer Science)

02 AUGUST 1999: F-4UCORSAIR (EAA AIRVENTURE '99, USA)

The holding point was crowded with vintage WWII fighters and a group of Mustangs had just taken off. The two F-4U Corsairs were holding at the beginning of the runway while the two F-8F Bearcats further down the runway were rolling for take-off; the F-8F's suddenly rejected the take-off and came to a stop together, one either side of the runway centreline. The spectators were unaware as to why they had aborted the take-off except that it was stiflingly hot and maybe something was wrong with their engines since they had held for an extended period with the engines idling.

With the two Bearcats holding on each side of the runway centreline 1,400 feet farther down runway 18, when for an unknown reason the two waiting Corsairs suddenly both advanced to take-off power and began their takeoff roll. A spectator remarked to his girlfriend who was standing beside him that this didn't look good as he could not see how the Corsairs could pass by the Bearcats. The thought did pass his mind that perhaps his sight angle was creating a parallax error and maybe there was more room than there seemed. Well, there wasn't.

Both Corsairs were just about to get airborne when they reached the stationary Bearcats. It looked like the tail on the lead Corsair came up just an instant prior to impact, the left main undercarriage took off about three-quarters of the right wing of the Bearcat spinning the Bearcat around on the runway while the Corsair continued on. It appeared that the wheels of the Corsair five feet off the runway, the left wing came down, scraped, came back up a bit and then the aircraft began a roll to the left while still pointed straight down the runway. This time the wing began to crumple, broke off and the aircraft cartwheeled with the engine being torn off as it hit, starting a fire at this time. It then appeared as if the right wing broke off and the cockpit section was thrown clear from the crash.

The second Corsair pilot took evasive action and ended up with damage to the end of one wing but managed to get the aircraft under control in the face of a pretty stiff crosswind from the right that prevailed at the time of the crash. There was obviously some form of communication failure or confusion for the Corsairs to attempt to take-off when the runway wasn't yet clear. The F4U/FG1's Corsairs lack of visibility over the nose is notoriously well known to its pilots, there is almost no forward view from a Corsair until the tail is raised.

The NTSB said it would look closely at aircraft communication procedures in use at the time of the formation take-off that ended with the spectacular crash. NTSB investigator Dave Bowling of the NTSB's Chicago office, confirmed that Laird Doctor's, Corsair had just become airborne when it struck the right wing of the Bearcat being flown by flight leader Howard Pardue, of Breckinridge, Texas, severing the outboard eleven feet of the Corsair's right wing. The Corsair then cartwheeled off the left side of the runway before bursting into flames and breaking apart. Doctor was thrown from the burning portion of the wreckage, which probably helped him survive. After being rushed to a Milwaukee hospital in critical condition, Doctor's condition was upgraded to critical but stable.

The aircraft involved in the collision were part of a four-plane flight that was to begin with tandem takeoffs of the two Bearcats and then the two Corsairs. Bowling explained that the warbird flights at AirVenture were under the control of an airboss from the Warbird Association. In effect, the Oshkosh tower turned control of Wittman airfield over to the airboss, who coordinated communications and sequenced the warbirds participating in the airshow. Although the airboss was not a certified air traffic controller, this system of handling warbird flights had been used successfully for years at Oshkosh and other airshows, according to Bowling. Bowling said the poor forward visibility of the Corsairs would have made it difficult for them to see the stationary Bearcats on the runway and added that preliminary data indicated that none of the four aircraft in the flight had suffered any mechanical failures prior to the accident.

The other Corsair, flown by Jim Reed, managed to just avoid the two Bearcats, one piloted by Pardue and the other by Tom Wood, but still suffered some left wingtip damage while banking away at the last second. The FAA was monitoring the airboss communication's channel at the time of the mishap and had an audiotape that the NTSB would review. A crucial part of the investigation was Bowling's interviews with the pilots and airboss about their taxi, takeoff and formation flight procedures, which were thoroughly discussed before each airshow.

The twin-seat Sukhoi Su-30MK attempted to pull out of a descent that had included three 'high alpha' downline rolls using vectored thrust. *(Aviation Week and Space Technology)*

19 JUNE 1999: NORTH AMERCIAN F-86E SABRE (NEW JERSEY, USA)

Entrepreneur and inventor, Steve Snyder, 64, the owner of South Jersey Regional Airport, Lumberton Township, New Jersey, USA, was killed in the crash of his F-86E Sabre Mk.6. He was flying a display for the Bonanza Society and impacted the ground during a low speed fly past. Steve Snyder, owned both the accident aircraft and also the airport and was also president of the Air Victory Museum, based at Vay, which owned the F-86. Visual meteorological conditions prevailed for the personal flight conducted under Title 14 CFR Part 91.

Reports indicated that the Korean war-era swept-wing jet went out of control after a low-speed, low-altitude pass down the airport's single runway. A witness, standing approximately 2,000 feet from the accident site, watched the aircraft take-off and perform several manoeuvres before flying a 'slow' high alpha pass to the west at approximately 200 feet agl. As the aircraft passed in front of the witness, it slowed, and started to sink. The aircraft's pitch attitude increased, and the witness heard an increase in power, followed by a bang, described as consistent with a 'compressor stall.'

Examination of photographs taken of the accident sequence, showed the aircraft's landing gear extended, speed-brakes deployed and flaps down, the landing configuration that would typically be used for the high angle of attack pass. In the first photograph, the aircraft was approximately 15º nose-up and wings level. In the second photograph, the aircraft was approximately 30 feet agl, at approximately 90º right bank and about 10º nose-down. In the third photograph, the right wing and nose of the aircraft had impacted the ground in an approximately 120º right-banked attitude.

12 JUNE 1999: SUKHOI SU-30MK (PARIS AIRSHOW, LE BOURGET, FRANCE)

Surely one of the most spectacular airshow crashes, the prototype Sukhoi SU-30 MK, Blue 01 crashed at the 1999 Paris Airshow, the third Russian aircraft to crash at the show since 1973. Previously, the TU-144 crashed in 1973 and in 1989, a MiG-29. The twin-seat Sukhoi Su-30MK attempted to pull out of a descent that had included three 'high alpha' downline rolls using vectored thrust. The pilot, short of the proverbial '50 ft extra' tried to recover by using full power and thrust vectoring, but the aircraft jet pipe clipped the ground at a pitch angle of approximately 15º with virtually zero roll and almost zero forward speed. As it struggled away from the ground, the left engine caught fire and test pilot Viacheslav Averyanov and navigator Vladimir Shendrikh initiated the ejection sequence, employing the now well-demonstrated Zvezda K-36D seats at approximately 200 feet.

At a press briefing the following day, Sukhoi general director, Mikhail Simonov, said preliminary analysis showed no technical failure. He made no mention of "pilot error," although he had previously used that term to describe the probable cause of the accident. Simonov attributed the mishap to a late decision by show organizers to shorten the display from eight to six minutes, forcing the pilots to cut several manoeuvres and redesign the sequence. Sukhoi officials claimed that the changes had made it necessary to modify the initial flight parameters in a number of manoeuvres, causing the duration of recoveries to be lengthened, with a loss of altitude and change in exit direction that were "difficult to predict."

Sukhoi said the original programme had been extensively rehearsed on a simulator, in a Su-31 aerobatic aircraft and on the Su-30MK. The programme was signed off by Simonov himself seven days before the aircraft arrived in Paris. On arrival in Paris, the crew made three training flights with the shortened programme, for show clearance. They added that chief pilot Viacheslav Averyanov was one of Sukhoi's leading test pilots, having participated in flight test programmes for the Su-27K Su-35 and the Su-30MK, which he had flown 140 times since its first test flight.

At the press conference, Averyanov explained that during the manoeuvre, he suddenly realized, apparently bothered by the sun, that he was flying too close to the safety perimeter and nearby houses. He said their sense of altitude was affected by "how the area was lit by the Sun." He yanked the aircraft sharply and attempted to recover from the descent with full power and thrust-vectoring control but the aircraft's port engine struck the ground and caught fire.

Averyanov said he tried until the very last moment to save the aircraft, “the aircraft was controllable to the last,” he said, “it showed wonderful performance, which allowed us to reduce our descent to a minimum. I was not disappointed in any way with its response.” Airshow Commissioner, General Edmond Marchegay lauded the pilots for recovering the aircraft and avoiding a catastrophe. However, he noted that flight routines are commonly changed at the last minute, and that the Russian crew had agreed to the changes requested. “If they agreed to the changes, that meant they thought they posed no particular problem.” The modified routine had already been flown three times before the mishap and had been approved by the Flying Control Committee.

Marchegay added that the French armaments agency, DGA, would investigate the incident to determine whether the pilots were flying outside the allowed safety envelope. Western pilots interviewed by Aviation Week & Space Technology indicated that the pilots were flying too low and had “clearly misjudged the descent.”

The accident was an embarrassment for Sukhoi, which had been stealing the show at exhibits around the world with the super-manoeuvrable Su-30 that utilised thrust-vector control to complete aerobatic manoeuvres that no other fighter could match. However, officials brushed off suggestions that it might hamper foreign arms sales, in particular the sale of 50 Su-30MKIs, based on the Su-30MK, to India.

In a Reuters report on 13 June 99, the pilot of the Sukhoi-30 apologised saying he accepted the blame after attempting an ambitious aerial manoeuvre. “Sorry, I did one too many revolutions in a flat corkscrew and I couldn’t pull her out. I didn’t have the altitude to get the plane out of the manoeuvre,” Averyanov was quoted as saying. Mikhail Simonov, who designed the aircraft, told Tass that he had no hard feelings towards Averyanov “who owned up to his mistake in piloting the aircraft”. From an analysis of the data taken from the flight recorder, the aircraft systems performed as advertised to the last. Even after the aircraft first clipped the ground and maintained contact with the surface for about 100 yards, the aircraft responded to the controls and the engines functioned properly. This allowed the pilot to execute a steep climb after touching the ground in order to guarantee safe ejection. If it were an ordinary aircraft without a thrust vectoring system, it would have dropped its nose during contact with the surface and flown into the ground. Amazingly the aircraft did not explode, neither during the moment when it first clipped the ground or when it impacted the ground after the pilots had ejected. Thus, Simonov concluded, putting aside the sad feelings about the loss of the valuable aircraft, the accident should be considered not just as a loss, but also as a source of unique information for analysis on aircraft behaviour in critical situations. Such information could not have been acquired by any other means, Simonov said.

6 JUNE 1999: HAWK 200 (BAE SYSTEMS, BRATISLAVA, SLOVAKIA)

A civil registered British Aerospace Hawk 200 demonstration aircraft crashed while participating in the SIAD ‘99 air display at the Milan Rastislav Stefanik airport, Bratislava, Slovakia. The Hawk 200 had been sent there to demonstrate alongside the Yakolev-130D and the Aerovodochody L-159, all possible contenders for the future Slovak acquisition of a light multi-role type aircraft. The highly experienced BAE Systems demonstration pilot, Mr Gordon Wardell, who had been the first RAF exchange pilot to qualify on the F-117A, was killed instantly.

The crash occurred at around 1.00 p.m. towards the end of a superb display, the pilot did not, or was not able to recover from a steep angled end of a barrel-roll and crashed into the runway. The aircraft exploded and slid along the runway end and over the perimeter-fence, where it killed a woman and injured four members of the public standing outside the airfield. The reported cause of the crash was “controlled flight into the ground” with G-LOC suggested as a possible contributory cause.

30 MAY 1999: WIRRAWAY (NEW SOUTH WALES, AUSTRALIA)

An Australian vintage aircraft *Wirraway* trainer (Australian manufactured Harvard T-6) was taking part in the Australia Naval Aviation Museum airshow in the New South Wales coastal town of Nowra when it crashed near the Naval Base HMAS Albatross, killing both occupants.

The pilot and his passenger died when the single-engine 1950s vintage Wirraway crashed just metres from the runway. They were doing handling displays when the aircraft departed and auto-rotated into a spin. A Naval spokesman said fifteen vintage aircraft were taking part in the airshow, watched by two to three thousand people. Witnesses described the accident as a control problem: “the aircraft was heading for the ground in a steep dive while yawing all over the place, at about 50 ft above ground level, it flipped over and hit the ground upside down”.

25 APRIL 1999: F-16 (USAF *THUNDERBIRDS,* FLORIDA, USA)

The USAF *Thunderbirds* were temporarily grounded following an incident in which two of their F-16C’s touched in mid-air. The incident occurred at Patrick Air Force Base, Florida during the Air and Space Expo ‘99. As the team began their aerial demonstration, the left horizontal stabilizer of the No.3 jet reportedly touched the right wing of the No.4 aircraft. The result to each airframe was minor damage, said to be “paint chipping and bent metal”.

The display was immediately cancelled and all the aircraft landed safely with no injuries to anyone. In fact, it was reported that the public didn’t even realise anything was wrong until ambulances rushed to the runway as the team landed. The team’s spokesman, 1st Lt. Guy Hunneyman, said it’s the only time he could remember the team having to cancel a show after such a mishap. The two pilots involved were Maj. Russell Mack and Maj. Scott Bowen, who had a combined total of 4,200 flying hours between them.

The *Thunderbirds* returned to their home at Nellis A.F.B. Nevada, to begin an investigation into the mishap. The following statement was then released on 29 April 1999: *“The Commander of the Air Force’s Air Warfare Center has suspended, until further notice, the 1999 U.S. Air Force Thunderbirds aerial demonstration show schedule. The suspension was made April 28. Maj. Gen. Glen Moorhead made the decision after reviewing circumstances surrounding an incident during an airshow April 25 at Patrick Air Force Base, Fla. “Safety is our No. 1 concern,” Moorhead said. “We have a responsibility to both the public and the team after an incident like this to step back and take a hard look at our practices and procedures.”*

“No one understands the importance of the Thunderbirds mission more than the men and women of Nellis Air Force Base and the people of the Las Vegas Valley,” he added. “The Nellis airshow is our way of thanking these same people for their support. It would be inappropriate for Nellis to have the 1999 airshow without the Thunderbirds, so we will wait for their return; after we have reviewed this incident thoroughly.”

On the 18 May 1999 the following report was released: “ *The Air Force Thunderbirds resumed flight training this week in preparation for resuming their 1999 aerial demonstration schedule. It is still unclear how long the Thunderbirds will train before they return to their show schedule; however, the team has cancelled demonstrations through May 29”.*

“Following a thorough review of the incident, Brig. Gen. Bill Lay, commander of the 57th Wing and the parent organization for the Thunderbirds, made the decision to recall a former, experienced Thunderbird pilot to the team to replace Capt. Russell Mack, one of the pilots involved in the mishap. Maj. Mark Arlinghaus, solo for the 1997 and 1998 Thunderbird teams, has begun training to fill the right-wing position for the remainder of the 1999 aerial demonstration season.”

“After analysing all material available to me, I concluded it was in the best interest of the Thunderbirds to bring back Major Arlinghaus,” said Lay. “As General Moorhead said last week, safety is our primary concern. We have a responsibility to the public and the team to take a hard look at how we do business after an incident like this. We stepped back and examined the make up of the team, the members’ level of experience, our training practices and manoeuvres...I’m confident the team is on the right track to resuming the demonstration season.” (Earl Watkins, USA, and SIG members John Cooper & Tom Kolk, USA.)

10 DECEMBER 1998: CT114 TUTOR (RCAF *SNOWBIRDS* TEAM, CANADA)

Snowbird No. 2, Capt. Mike Vandenbos, was tragically killed following a mid-air collision during a training flight. Although Capt. Vandenbos ejected successfully before the aircraft crashed, there was insufficient height for his parachute to fully deploy and he was killed on impact with the ground. However, it was discovered that the airlock fasteners on the pilot’s rigid seat survival kit (RSSK) were not connected when seat/man separation was initiated. The pilot's maritime lanyard was also not connected. Post ejection contact occurred between the pilot, the ejection seat and the unattached RSSK.

A formation of six aircraft from 431 (AD) Sqn was conducting training manoeuvres to the south of CFB Moose Jaw and were in arrow-formation with the outer left echelon position vacant. The manoeuvre comprised a left wingover followed by a descent to a reversing right level turn. The appointed team leader was not present and the formation was being led by Snowbird No.7.

As the formation rolled through approximately 50º of right bank in a level turn at 1,200' agl and 260 KIAS, the underside of the left wing of aircraft No.6 contacted the upper surface of the right horizontal stabiliser of aircraft No.2. The entire horizontal stabiliser and part of the vertical stabiliser separated from aircraft No.2 and the aircraft dropped through the bottom of the formation. The No.2 aircraft then rolled inverted under extreme negative G, stalled and fell to the ground, still in an inverted attitude. The pilot ejected from the aircraft but suffered fatal injuries upon impacting the ground.

The preliminary investigation also found no evidence of pre-impact material failure or system malfunctions that might have contributed to the accident. At the moment of impact, the calculated position error between aircraft No.2 and aircraft No.6 was approximately 14 ft laterally and 5 ft vertically. (RCAF Air Force Directorate Flying Safety)

19 SEPTEMBER 1998: AT-6 HARVARD (RENO AIR RACES, RENO, USA)

It happened on Sunday, around 9:20 a.m., at the start of the six aircraft AT-6 Silver Race; the aircraft were all lined-up and coming down the chute. The pace aircraft had just given the pilots a race and *'Mis Behavin'* piloted by Ralph Twombly was a little higher then the others; it dove a bit to start the race and collided with '*Big* Red' flown by Jerry McDonald. Twombly lost his empennage in the collision and pitched up so violently that the wing failed off of '*Mis Behavin'* which spun into the ground close to a house at the extreme left of the show centre. '*Big* Red' was able to land and parked at the right side (adjacent to the military displays) of show centre. Later, when *'Big Red'* taxied by the grandstand on it's way back to the pits, it appeared that the left wingtip and left aileron was missing and there were chunks missing from the leading edge. The very sad thing was that both pilots were experienced race pilots, Ralph Twombly had won the AT-6 races twice before; 1977 in *'Spooled Up'* and 1982 in *'Mis Behavin'*.

Comment from a spectator: "The clipped T-6 seemed to just hurl through a trajectory without violent tumbling and hit with a big thud" he said, "Man, that is a 'dangerous' way to get one's thrills; got to admire their courage to do this though, but I can't imagine how they justify the risks". TV news reports said that it was the second fatal accident at the Reno in 1997, in fact, in the previous year, the Pond racer crashed, killing its pilot.

These incidents and the ongoing intense competition have made the racing fraternity extremely safety conscious. Pilot briefings before each day of racing stress the necessity of flying safely while trying hard to win. A pilot making a pass, for example, must never lose sight of the aircraft he is overtaking. Infractions of this rule, or any other flying that is obviously dangerous, results in the immediate suspension of the offender for the remainder of the meet.

15 SEPTEMBER 1998: CHENGDU F-7 CHINESE PLA (*AUGUST 1ST AEROBATIC TEAM,* TIANJIN, CHINA)

The first public appearance of China's People's Liberation Army Air Force (PLAAF) national formation aerobatic team, *August 1st Aerobatic Team*, was on 20th December 1997 at Tianjin, China. They were thereafter scheduled to give more than twenty displays throughout China during 1998, including the China Airshow at Zhuhai in November. Equipped with six Chengdu F-7EB jet fighters, the latest PLAAF variant of the MiG-21F, and painted in a smart red and white colour scheme, the aircraft were also equipped with smoke generators. It was originally planned to mount the team on the Shenyang F-8II, but the more manoeuvrable F-7EB was chosen instead.

Six months later, the *August 1st Aerobatic Team* suffered the loss of three of their aircraft in a mid-air collision near Tianjin in June 1998. They tried to reform in line abreast during a loop but three of the aircraft collided with each other resulting in the death of the three pilots. The pilots did not eject. This tragic loss cast doubt over the future of this 'young' team, which had only given their first performance in December 1997.

23 JULY 1998: MIKOYAN MIG-29 (HUNGARIAN AIR FORCE, KECSKEMET HUNGARY)

A Hungarian fighter pilot died when his Russian-made MiG-29 jet crashed during a media preview a few days before the Kecskemet Airshow some 75 kilometres (40 miles) south of Budapest. "He was in the fifth minute of a low-altitude aerobatic sequence when he hit the ground," Lt. Col. Istvan Teglas, commander of the Kecskemet Air Brigade told Reuters at the crash site. "The pilot was flying at tree-top level, preparing for a weekend air-show in Kecskemet", Teglas said. The exact cause of the crash remained unclear, since there was no radio communications with the air traffic control tower indicating any abnormality". The MiG-29 was scattered over a 200-metre wide space in the middle of a wheat field two kilometres from the airport. Hungary, on becoming a member of the NATO military alliance, had received the MiG-29s from Russia in exchange for earlier debt and this accident was the first involving one of the MiG-29s in Hungary.

The prevailing atmospheric conditions were rather extreme, a very hot and dry day with the outside air temperature at between 32ºC and 35ºC. The pilot had performed low-level manoeuvres directly after takeoff, then turned into a left-hand turn for a low-level, high-speed pass. In the turn however, he realized that he lost airspeed and height and then selected full throttle and then afterburner. The familiar smoke trail of the RD-33 engine appeared transiently but then faded after approximately 5 seconds.

A Hungarian MiG-29 instructor said on TV that "the engine didn't produce enough power because of the density altitude". "It happened at approximately 120-150 feet agl and as he tried to pull up, he certainly lost more airspeed and height. The aircraft was now terribly slow and it fell down like a leaf. All we could see from the perspective of the TV camera was the aircraft disappearing below tree-level. About a half a second later, a small black object was seen to fly out from the trees and then fell back. Another moment later...explosion!"

"The pilot obviously thought until the last moment that he could retrieve the situation but ejected very late at about approximately 45º bank angle but there was insufficient altitude for the parachute to deploy". The pictures taken of the crash-site showed that the fighter fell onto its belly. "I'm not a pilot but I know that 30-35 flying hours per year, on average, isn't enough to ready the soldiers to solve any of these lethal situations. This is in contrast with the NATO minimum of approximately 160 hours", he said. (Reuters)

5 JUNE 1998: HAWKER HUNTER F4 (DUNSFOLD, UK)

The 42-year old pilot of a privately owned Hawker Hunter vintage jet died as he 'stayed' with the aircraft while an on-board fire raged furiously during a display practice for the upcoming Biggin Hill Air Fair. Although the pilot was highly experienced with 10,100 hours total, he had only eight-hours on type.

The Hunter formation, led by the pilot of the two-seat Hunter T7, planned to carry out a 'pairs display' practice at Biggin Hill for the airshow on the following day. Following a series of engine starting problems with the jet, and after experiencing bad weather at Biggin Hill, the synchro-pair of Hunters decided to practice at Dunsfold instead. After lunch and a briefing for the afternoon's flights, the pair prepared for departure from Dunsfold, but this was delayed again for about five minutes by some minor problem with the Hunter F4 after engine start-up.

Clearance for the display was duly granted up to a height of 2,500 feet and the pair then flew their complete display sequence. They then decided to repeat the practice display. The final stages of the display sequence involved opposition rolls, to be followed by the Hunter F4 turning right through 45° away from the 'crowd-line' to set up for a 'gear and flaps' low speed pass. The other Hunter would meanwhile position on a right-hand circuit so that both aircraft could then perform another pass together in front of the crowd-line, with the Hunter F4 at low speed and the Hunter T7 at high speed.

This was to be the last manoeuvre before both aircraft joined up for a 'run-and-break', prior to landing. As the T7 reached the end of downwind on his right-hand circuit, the pilot looked to his right to acquire the F4. However, since he could not see the other Hunter he transmitted "PUT

YOUR SMOKE ON I'VE LOST YOU". Almost immediately the pilot of the F4 transmitted "MAYDAY MAYDAY MAYDAY, ENGINE FAILURE, HEADING FOR THE FIELD". However ATC did not reply to this transmission, and the Mayday was re-transmitted. The pilot of T7 then transmitted "...THE FIELD'S ALL YOURS YOU GO FOR IT". ATC then replied ".... YOU'RE CLEARED TO LAND". The pilot of the T7 then transmitted "KEEP PRESSING THE RE-LIGHT BUTTON GO FOR THE MA---" (intending to complete the transmission with the words "MANUAL FUEL").

At this stage the F4 was at some 500 to 700 feet agl and a flame, estimated at some ten feet in length, was seen emanating from the aircraft's jet pipe by several witnesses on the ground. A second flame was observed emanating from the side of the fuselage forward of the tailplane, at the base of the fin's leading edge. The aircraft turned left towards Runway 25 and barely cleared trees on the south-eastern boundary of the airfield before it passed over the perimeter track at a height of some 20 feet agl and approximately 10º of left bank. The aircraft then struck the disused runway short of Runway 25 with its left drop tank whilst at an angle of 40º to the runway heading, before landing heavily on its main landing gear. It then bounced back into the air and rolled left to a bank angle of approximately 65° before striking the ground a second time with its left wing tip. It then pitched downwards and yawed left onto its nose, impacting the runway surface before sliding laterally on its belly, at one stage backwards, across the runway and grass beyond. It finally came to rest in an upright attitude on the northern side of Runway 25.

This impact sequence was described by some witnesses as 'something like a horizontal cartwheel'. The pilot, who had been flung from his safety harness during the impact sequence, suffered fatal injuries. The emergency services, which had been on standby because of the practice display, arrived on the scene almost immediately.

08 MAY 1998: CESSNA A-37B (ROKAF, *BLACK EAGLES* TEAM, KOREA)

Two Cessna A-37B's of the Black Eagles suffered a mid-air collision in which one aircraft crashed killing the team leader, Major Won-Hoon Cho while the other aircraft involved, landed safely.

21 APRIL 1998: STARLIGHT WARP ULTRALIGHT (EAA SUN 'N FUN, USA)

A Starlight Warp ultra-light aircraft crashed shortly after takeoff from the ultra-light runway at Lakeland, Florida, during the Sun 'n Fun EAA Fly-In. The pilot, 51-year-old Larry L. Collins, of Dayton, Ohio, was killed in the crash. The aircraft apparently lost lift while turning into the pattern after take-off. (AOPA News)

19 APRIL 1998: BOEING STEARMAN (*RED BARON STEARMAN SQUADRON*, USA)

On Sunday afternoon, 19 April 1998, at the Kissimmee Airshow of the Stars, Fla., two members of the *Red Baron Stearman Squadron*, the U.S.-based four-aircraft civilian aerobatic team, were killed when their Stearman biplanes collided in mid-air during an airshow. A spokesman of Schwan's Sales Enterprises, the squadron's corporate sponsor, identified the pilots as James Edward Lovelace of Seward, Neb., and Randall L. Drake of Waukesha, Wis.

The four-aircraft team while manoeuvring during a 14 CFR Part 91 acrobatic flight, was flying in a diamond formation at approximately 1,500 ft above ground level when the slot aircraft slid into one of the wingmen and the two aircraft became entangled, tumbling from the sky until they struck the ground and crashed in front of more than five thousand spectators. Both pilots were killed and although no one on the ground was hurt directly as a result of the crash, two police officers suffered minor injuries when they tried to pull the pilots from the burning wreckage. The weather may have contributed to the collision as the two aircraft were winding down their performance. The Kissimmee Airport reported the prevailing weather conditions at the municipal airport as 25-mph winds with gusts up to 30 mph under low clouds.

The flight lead for the *Red Baron Stearman Squadron* stated that they had completed a half Cuban Eight manoeuvre and rolled upright from the inverted position at 2,100 feet agl, then descended down to 1,600 feet agl and started to position themselves in a climbing turn to conduct a loop in a diamond formation when the accident occurred. Witnesses and video obtained from numerous TV stations revealed that the lead aircraft, number three right wingman, and number four left wingman started pulling up out of the dive to initiate the diamond loop formation when the number two trail aircraft continued to descend, and collided with the left wingman. " (NTSB)

A witness said: "It appeared as though Richard Drake's plane suddenly pitched down and stabbed into Jim Lovelace's plane. This was not a minor wing tip touch of getting too close, but rather a very sudden pitch down after they had just completed a coordinated routine. The aircraft stuck and tumbled together all the way down and then caught fire upon impact with the ground". Spectators reported that when they collided, "you could hear the loud clap of the wings hitting each other". "They got intertwined and they couldn't break off, then they started falling very rapidly. Reports said that one pilot died on impact and the other survived the crash and post-crash fire long enough to get to the hospital, but he died there. The police got there first with hand-held extinguishers". (Reuters)

19 MARCH 1998: PISTON PROVOST (SAAF MUSEUM, SWARTKOPS, SOUTH AFRICA)

A highly experienced test pilot from Denel Aviation crashed at AFB Swartkops, South Africa while practicing for an upcoming Museum Airshow day. The restored Piston Provost failed to recover from a low-level stall-turn, and impacted on the airfield almost in the three-point attitude. The pilot initially survived the crash but the ensuing post-crash fire engulfed the cockpit and induced severe burns; he was evacuated to hospital but died later. There was no collateral damage and no spectators on the ground were injured. The cause of the accident was attributed to human error in that there was insufficient height to recover from an aerobatic manoeuvre.

The pilot, due to fly in a display two days later, was not current on display flying on the Provost although he was a highly experienced pilot. He had received a dual check but because the weather was unsuitable for upper air work, only circuit work was practiced. The weather improved and he proceeded to the general flying area but found the cloud base at 6,500' AMSL (ground level being 5300' to 5500'AMSL) to be too low for aerobatics.

On rejoining, the pilot told ATC that he would commence his 'bad-weather' sequence practice. His show appeared to progress as set out, albeit slightly low. At the point where the pilot was to commence a half loop followed by an aileron roll, he pulled almost vertically and converted the manoeuvre to a stall turn to the left. On recovery from the stall turn, with insufficient height to complete the pullout, the aircraft impacted the ground in an almost three-point attitude. There was speculation that the pilot, realising the possibility of entering the overcast during the pull-up for the half-loop, decided to convert the manoeuvre into a stall turn.

01 MARCH 1998: AIR TRACTOR 802A (AUSTRALIA)

A pilot was fatally injured when his Air Tractor 802A impacted the ground at an airshow following a water drop in a fire-fighting demonstration. The aircraft approached the drop site ten knots faster than recommended and during the water release, the aircraft pitched up and entered a steep climb. The nose continued to pitch up with an increasing climb angle but there was no evidence that the pilot had made any elevator input to reduce the steepness of the climb.

The aircraft climbed straight ahead for a short distance before departing controlled flight to the left, the bank angle increased to about 90º and the nose pitched down to an almost horizontal attitude. At about 450 ft agl and at low speed, the aircraft rolled inverted and entered the incipient stages of an inverted spin. The aircraft impacted the ground still inverted, in a wings level attitude at a nose down angle of approximately 45º.

The AT-802A flight manual stipulates that during load release, a sudden nose-up pitching moment can be expected. Experienced pilots reported that the intensity of the pitching moment depended on the aircraft's speed and the rate at which the hopper was emptied. Obviously, the higher the airspeed, the larger the pitch rate.

The pilot was experienced enough to deal with the nose-up pitching moment associated with the water release but it is possible that the pilot intended to climb the aircraft steeply after releasing the load in an attempt to increase the visual impact of the display. It is doubtful though that such a manoeuvre could have been safely completed since the flaps were extended at maximum deflection and the rate of energy bleed and empennage blanking could have significantly reduced the elevator power available to recover from the steep climb.

12 OCTOBER 1997: MESSERSCHMITT BF-109 *'BLACK 6'* (IMPERIAL WAR MUSEUM: DUXFORD MUSEUM, UNITED KINGDOM)

'*Black 6'*, the Duxford Museum's and the world's only flying Bf-109G-6, on her penultimate flight at the Duxford airshow, overshot the runway during a forced landing following a loss of engine power during the display. Irrespective of the arguments and pleas on both sides to extend her flying career, this accident sealed the fate of this glorious aircraft. The *'Black 6'* team had found out the Ministry of Defence's decision on their aircraft the previous day – the aircraft, due to its value as the only "one-off" in air-worthy condition, would definitely be returned to the RAF Museum Hendon at the end of the 1997 airshow season in the UK.

All the team's previous petitioning and lobbying of the RAF and MOD to keep her flying had been unsuccessful; even going so far as to get the public to approach their MPs to raise the issue at parliamentary level. The aircraft was due to be grounded at the end of the month when the four-year display agreement struck between the Imperial War Museum and the MOD in 1992, was to be terminated. The IWM had requested the MOD for an extension since the 1993 season had been lost due to technical problems and a one-year extension had already been granted.

Fire and rescue services were on site almost immediately following the near three-point attitude impact. (SAAF Directorate Flying Safety)

Throughout the display sequence, white vapour was seen trailing the aircraft and the sound of a rough running engine, was reported to the pilot. Then, in a diving manoeuvre it was seen to emit a trail of white smoke, perhaps indicating failure in the top end of the engine, or the cooling system. According to one newspaper report, the engine failed at a critical position relative to the airfield where the aircraft was too high to land straight ahead, but too low to put in a 360° turn. Without declaring an emergency, the pilot announced he was landing and circled to line up for an into-wind landing from the western end of Duxford.

The pilot, Air Chief Marshal Sir John Allison, Commander-In-Chief RAF Strike Command, performed a 'dead stick' landing. It would appear that having suffered a considerable loss of power, the pilot had no option but to get the '109' down as quickly as possible. Another circuit to lose height and speed gradually would have put him too low on the approach, so he had to lose height quickly from a high approach which resulted in a very fast landing with no option of going around. The fast, steep approach lead to the pilot having to make several attempts to get the aircraft to settle on the runway, but excessive airspeed and insufficient runway length were against him.

The aircraft landed on Runway 06 and the fresh NW wind at the time, would not have helped. Part of the eastern end of the airfield had effectively been lost when the M11 Motorway was constructed several years earlier and the airfield is screened from the road by an earth-mound. The aircraft kept rolling and as it overran the runway, the pilot pulled the aircraft off the ground and must have raised sufficient engine power to 'jump' over the embankment at the end of 06, over the M11, and into a grassed field on the other side. Following recent heavy rain, the ground was soft and the aircraft dug in and 'nosed-over' at a relatively low speed. The emergency services, were on site quickly and the uninjured trapped pilot, strangely enough, requested the rescue services not to cut him out but to wait until a crane was brought in to lift it up so he could make his exit. All credit to the pilot for not wanting to damage the aircraft any further but the decision to risk his personal safety, was questionable.

It is here that pilots make critical mistakes – in their misguided judgement that the aircraft is more important than the pilot, they take actions which may be honourable in the cause of saving a valuable heritage aircraft, but stupid in the case of saving the valuable life of the pilot.

To emphasise the point, Charlie Hillard, was killed in a similar accident following a solo aerobatic performance at the Sun 'n Fun EAA Fly-In at Lakeland, Fla., in 1996. When the aircraft flipped onto its back during the landing rollout. According to the preliminary NTSB report, the pilot, suffered fatal injuries and the aircraft suffered substantial damage. Polk County (Fla.) Medical Examiner Alexander Melamud concluded Hillard died of 'positional asphyxia' after his chest and back were compressed by parts of the cockpit.

Once rescued from 'Black 6', Allison was taken to hospital for a medical check-up. Damage to the aircraft was assessed as a twisted and bent rear fuselage, damage to the tail and a broken propeller, but otherwise, the aircraft was in one piece. John Allison, was not only a very experienced display pilot and had been flying historic aircraft at Duxford for many years, but he was also the test pilot for the Bf-109 and had flown the aircraft on many displays. Allison was also a very experienced glider pilot and owned several vintage gliders as well as some of the powered aircraft he flew. Nonetheless, a sad day for warbird aviation . ('*Fly Past Magazine*' Oct 97).

Then there are also the success stories. Ironically, it was also at Duxford's Flying Legends airshow in 1995 that Mark Hanna successfully dead-sticked Hans Dittes' DB605-powered '109' back onto the airfield following a total loss of power. A spectator 'on the fence' at the M11 side in front of the parking line and listening to the radio, heard Hanna call nearly immediately after the take-off of the two 109's, that he was landing. Although no emergency was heard to be declared, it was obvious that there was a problem and that one of the 109's was returning. Rolling out on final, the engine was dead. Since the 109 does not have a feathering system the prop was wind-milling and it would have appeared to the casual observer that the engine was still running. The landing appeared normal, the problem must have been serious because when Hanna exited the aircraft, he went to his knees and kissed the ground – 'a professional airshow pilot'.

20 SEPTEMBER 1997: PITTS SPECIAL S-24 (CONFEDERATE AIRSHOW, ST MARCOS, TEXAS, USA)

The crash was the first in the show's six-year history, Jim Kincaid, owner of Kaimana Aviation, was killed when his aircraft crashed during the Confederate Air Force Airshow in San Marcos, Texas. Kincaid was flying his Pitts Special S-24 and had been putting it through its paces when the aircraft lost altitude and crashed into the airport infield near thousands of spectators. The aircraft did not catch fire but there appeared to be a lot of smoke, a spokesman said. "The aircraft levelled off from a steep vertical manoeuvre and crashed on the bottom of the plane. He kind of hit hard and fast." No spectators were injured and no collateral damage was caused and the show continued as scheduled.

An experienced and popular performer at Airshows across Oklahoma and around the USA, Kincaid had recently preformed in his Pitts Special S-24 "Oklahoma Crude," at Ponca City Airshow, Wichita's Aerodrome Days at McConnell Air Force Base and Strother Field and had also previously flown at San Marcos, where the Confederate Air Force gathered annually.

14 SEPTEMBER 1997: F-117A (BALTIMORE, MARYLAND, USA)

On 12 December 1997, Air Combat Command released the accident investigation report of the F-117A stealth fighter from Holloman Air Force Base, N.M. that crashed on 14 September 1997 near Baltimore, Md. The aircraft had just completed its third pass during an airshow flyover at Martin State Airport and the pilot was initiating a climb-out for departure when he felt the aircraft shudder and the left wing broke off. The aircraft crashed into the residential area of Bowley's Quarters, Md., and caused extensive fire damage to several homes and vehicles, miraculously without fatalities but four people on the ground were slightly injured and ten families were displaced by the crash.

The F-117A and Knight were assigned to the 7th Fighter Squadron at Holloman AFB, N.M where Knight was an experienced instructor pilot and had more than 2,770 flying hours, 500 in the F-117A. The aircraft had left Syracuse, N.Y., and was performing at the airshow while en route to

Langley AFB, Va. and was one of two F-117As temporarily located at Langley to support community and military airshows in the eastern United States.

The F-117 almost stopped dead in midair after the wing separated, then fell straight down, rocking back and forth around the pitching axis, descending vertically and impacting in a nearly level attitude. It was approximately twenty seconds from the wing failure to impact and the pilot stayed with it until about five seconds before impact, landing about 150 feet from the wreckage. The pilot, Maj. Bryan K. Knight, ejected and was fortunate to receive only minor injuries landing only metres from the post impact fireball.

The accident investigation report concluded that the cause of the accident was structural failure of a support assembly in the left wing known as the 'Brooklyn Bridge'. The failure was attributable to four of the thirty-nine fasteners missing from the assembly which was apparently improperly reinstalled during a scheduled periodic inspection in January 1996, a maintenance error. The entire fleet of 53 F-117 Nighthawks was inspected during a command-directed precautionary stand down and none were found to have the same defect. (ACC News Service)

A witness to the accident recorded that the F-117 "went down more like a falling leaf than an airplane". Video footage showed the port wing flapping severely for a second before the whole structure broke off the fuselage. Flutter had been discovered in the initial envelope expansion testing of the F-117 and a mechanical fix was introduced to stiffen the elevon attachment point and the hinge; the aircraft had never had a problem operationally until this incident.

Another witness reported: "I saw a large, black object drop away from the aircraft and wasn't sure exactly what had failed". From the video of the accident, it appeared that the left wing failed up and back, and the F-117 immediately rolled left and pitched-up violently. There was a white puff of vapour visible as the wing separated, which could have been hydraulic fluid or fuel. The main undercarriage was extended partially just before the aircraft disappeared behind a stand of trees on shore.

Poor maintenance and configuration management remain a threat to the well-being of any pilot, but in particular, the display pilot who is required to operate an aircraft on the edge of the envelope at very low altitudes. Dubious structural integrity of the aircraft is the last thing that a display pilot needs to be concerned with. In 1993, The South African Air Force Aermacchi MB-326 of the national formation aerobatic team, the *Silver Falcons* , suffered a major accident when the wing of the singleton broke-off while pulling out from a loop. The cause, poor maintenance and even poorer configuration management had allowed the aircraft back into service without rectification of a known wing main spar crack. The rapid departure of the aircraft coupled to the low altitude at which the failure occurred, resulted in the death of the pilot who ejected outside ejection seat parameters.

26 JULY 1997: XTRA 300 (ROYAL JORDANIAN AIR FORCE, OSTENDE, BELGIUM)

The *Royal Jordanian Falcons* solo-display aircraft crashed adjacent to a Red Cross tent and burst into flames flinging wreckage around the spectator's area at the Flanders "Fly-In and Airshow", Ostende, Belgium, at about 5 p.m. local time, on Saturday, 26th July 1997. Initially, eight people died including the pilot, and 40 others were injured. A ninth person died in hospital the next day.

The pilot, Captain Omar Hani Bilal, was a highly experienced aerobatic pilot that had been with the team for several years. Eyewitness reports vary but initially included claims that the Xtra 300 appeared to suffer a loss of power or was caught by a gust of wind. The pilot was performing the "lomcevak", or "tumbling" manoeuvre which the team, and indeed the Xtra 300 aircraft, is famous for, and for whatever reason, failed to recover from it. Other reports stated that the pilot simply appeared to lose control, although this would be a natural conclusion to reach by those who are not fully aware of the nature of some of the violent "flick" or tail-sliding manoeuvres incorporated into the *Royal Jordanian Falcons* solo routine. What was not understood was just why the aircraft appeared to be performing overhead the spectator enclosure off the official display line, which was strictly against European airshow safety regulations.

As soon as the *Turkish Stars* had finished their display routine, rain started and most of the public left to seek cover, many found it in the Red Cross tent that ended up in the way of a burning Xtra 300. Several spectators were burned, the Xtra had a surprisingly large amount of fuel on-board and following impact, it worked very much like napalm splashed in the direction of the public. A fleet of ambulances and military helicopters ferried the wounded to hospitals as far away as Brussels while others were treated at special 'burn units' at hospitals in the Flanders region.

The media hysteria and hype had only one question: "After the *Frecce Tricolori* 's accident in Germany, didn't all European nations change display rules so that a display aircraft never carries out manoeuvres over the crowd?" Indeed, after the 1988 crash at Ramstein, it was forbidden to fly over the crowd, but this accident was partly caused by very strong on-crowd wind resulting in poor showline control.

The pilot's body was flown back to Jordan on a Jordanian Air Force Hercules on Sunday, 27 July, following a short ceremony on the tarmac. The airshow was to have been a two-day event, but the Sunday show was cancelled and an immediate inquiry was launched. One experienced airshow spectator commented that: "Having attended numerous Belgian Airshows over the years also Dutch and Swedish, I am of the opinion that Belgian ones are (until something bad happens) somewhat medieval in appearance. Kids running about on the grass runway at the same time as an aircraft makes a touch and go landing, horse-mounted policemen almost getting their heads chopped of by a swinging Alouette chopper blade, a Britten Norman Islander pulling up 25 metres in front of the public at 'grass-top' level. It makes thrilling fun, until….??? In this particularly unfortunate case, the pilot was highly experienced but the weather was extremely poor, with rain and strong gusts of wind.

It is important to note that this particular display was a solo routine, part of a competition, and the RJAF pilot was the last to display, not part of the Falcon's overall display. The question that could be asked is: "How appropriate it is to put up an aerobatic competition at large airshows?" About four performers were flying to the 'Mission Impossible' theme, among them were world aerobatic champion Nikolai Timofeev, Francois Brocart, Frank Versteegh and the solo *Royal Jordanian Falcon* . He was the last to perform and he might have wanted to do his best stretching the limits after seeing the other three contenders, but there is little you can do to match Timofeev. It barely made any difference, however, because it was raining and there were not too many spectators left.

For what it is worth, a Dutch display pilot who was interviewed by Belgian TV, declared that it was wrong to perform this manoeuvre at such low altitude. He also criticised the Jordanian pilot for repeatedly breaking the rules repeatedly by overflying the crowd line. The Belgian minister of defence, Mr Poncelet, thereafter prohibited airshows on military airfields until the safety regulations and their application had been reviewed.

What is of concern in this accident is that the Flying Control Committee did not reinforce the show regulations! Just before the Jordanian crash, the *Turkish Stars* with half a dozen or so F-5s, were reportedly buzzing the crowd. One spectator declared: "I was standing at the edge of the public area about a metre away from the barrier separating the public from the flight line, I did not feel happy about the F-5 flying. I certainly have never been so close to the screaming jets at any of the US Airshows I have attended – they did some manoeuvres toward the public. If the public chokes on the smoke coming from the smoke generators, it is too close!"

26 JUNE 1997: AT-3 TRAINER (CHINESE AIR FORCE *THUNDER TIGERS* TEAM, CHINA)

The Republic of China *Thunder Tigers* team suffered a tragedy while on a five-ship practice flight from their base at Tapel/Kang-Shan airbase. During a four-point roll, one of the team's AT-3 jet trainers crashed at the Chinese Air Force Academy, killing pilot Sqn Ldr. Hsu Hai-Hua. The cause of the crash was mooted as possible mechanical failure.

22 JUNE 1997: FORMULA V HOMEBUILTS (LONG ISLAND, NEW YORK, USA)

A Kentucky pilot was killed and a Wisconsin pilot injured when their two aircraft collided in mid-air while performing at a Long Island, New York airshow. 51-year-old Richard Goodlett, of Louisville, Ky., President of the Formula V Air Racing Association, Inc., was airlifted to University Hospital in Stony Brook, N. Y., where he died from his injuries. 37-year old Christopher Kalishek, of Madison, Wisc., was admitted to University Hospital in critical condition with a punctured left lung and multiple compound fractures.

The midair collision occurred between the two ‘Formula V’ competition aircraft at the end of the two-mile, eight-lap air race during the ‘Wings Over Long Island’ airshow at Gabreski Airport. Four aircraft were competing in the race over the closed course marked by six pylons affixed to the ground.

Dick Goodlett and Chris Kalishek were in a close race for second place during the last heat of the day. Goodlett’s aircraft was set up to accelerate quickly off the line, but was slower around the course, and as such, his tactics were to fly very low, especially on the upwind leg. The start/finish line was on the upwind leg and at the finish, they were neck and neck with Goodlett still down on the deck at 50 ft and inside of Kalishek (at approximately 150 ft) rounding the first pylon after the finish. Goodlett apparently pulled up and his right wing struck Kalishek’s left wing root from below and Goodlett’s aircraft spun out of control and crashed, erupting into a fireball. Kalishek’s aircraft apparently had a more oblique impact but no fire. This was the first airshow on Long Island in twenty years, the last airshow also ended with a pilot fatality.

21 JUNE 1997: SUKHOI SU-27 FLANKER (RUSSIAN AIR FORCE, *RUSSIAN KNIGHTS*, SLOVAKIA)

One of the *Russian Knights* Su-27 Flankers ‘belly-landed’ in Bratislava, Slovakia, as the team arrived to take part in the SIAD ‘97 airshow. The four-ship formation had performed a display at Zeltweg, Austria, that morning and then flew on to Bratislava, arriving there at about 3 p.m. After a few arrival manoeuvres, the team broke for individual landings.

Landing in turn, the pilot of the third aircraft (Flanker 15) allegedly forgot to lower the undercarriage. The aircraft touched down on the runway and skidded along on it’s nose and ventral fins, creating a shower of sparks as it careered down the runway. The pilot deployed the ‘dragchute’ and the Flanker ground to a stop half way down the runway. The remaining Flanker, landed safely on the same runway after checking and verifying that sufficient runway length was available.

It then took about three hours to jack the stricken aircraft up and lower it’s undercarriage before it could be towed away for repairs, which meant that the remainder of the Saturday airshow was limited to helicopter displays, due to the runway blockage. The Sunday show went on as normal, with the *Russian Knights* performing a three-ship routine. There was very little damage to the Flanker after this incident, and it was flown back to Russia two days later.

14 JUNE 1997: WESTLAND LYNX MK80 S-170 (DANISH NAVY, WARSAW POLAND)

A Danish Navy Westland Lynx S-170 crashed during an airshow at Goraszka Air Picnic, Warsaw, Poland. The helicopter took off and made two fast passes in front of the public gallery but then crashed into the ground recovering from a wingover. The cause was attributed to human error – the pilot pulled out of the wingover recovery dive too late. There were no fatalities and the crew sustained only minor injuries; one broken leg. The injured crew were flown to the Warsaw’ military hospital in the ‘medevac’ helicopter. Amazingly, the damage to the S-170 was repairable and the aircraft was overhauled and returned to service. (Images Pawel Bondaryk, Aviation.pol.pl)

1 JUNE 1997: NORTH AMERICAN F-86 (COLORADO, USA)

The 63-year-old pilot of a Korean War vintage F-86 Sabre, Jack Morris Rosamond, a highly experienced, retired United Airlines pilot, crashed while performing a modified half-Cuban 8 at the Jefferson County airport northwest of Denver, CO. No one else at the Airshow Colorado 1997 was injured but the organizers cancelled the remainder of the show, which would have included a demonstration by the *Thunderbirds*.

Watching with 60,000 others, a witness reported that “to the end, the loop seemed smooth and under control. He just ran out of height”. Speculation on density altitude was rife, the airport elevation is approximately 5,600 ft, and the temperature was approaching 90ºF (32º C) at the time of the accident. The aircraft hit the ground at the bottom of a loop, belly-first. “It was a high-energy impact. There was more energy in it than anything I’ve seen,” said Norm Weimeyer, chief of the Denver office of the NTSB who headed a team of investigators examining the scene.

Another witness reported that from his perspective: “The angle that I saw it at showed that he was pulling out of the loop but just didn’t have enough height”. A picture in the Denver post the next day showed the aircraft at impact with a 15º nose-down pitch attitude. A Ball Aerospace security guard, who saw the whole thing from about 400 yards away, estimated that if the pilot had 50 feet more altitude, he would have made it. Some witnesses speculated that the aircraft seemed to stall before the crash. A comment by one of the spectators was: "I have to also say that the airshow was very chaotic. I had no clue what was going on. The official programme just happened to be missing any sort of schedule". Not unexpectedly, this accident also raised the question by many aviation people: "What was the 'g'-effect on a 63 year-old" in a Cuban-8 manoeuvre? Should pilots of this age still be flying low-level aerobatics?"

04 AUGUST 1996: AEROTEK PITTS SPECIAL S-1S (PITTSBURGH, PENNSYLVANIA, USA)

A highly experienced veteran stunt pilot, Clarence Speal, died after his bi-plane Pitts-Special plunged into the Ohio River during an airshow for the Three Rivers Regatta, Pittsburgh. Pulling up from a loop and entering into downline snap-rolls, the aircraft entered an uncontrollable spinning dive after both wings on the left hand side of the aircraft folded as the wings failed at the attachment points. The aircraft continued in an inverted attitude descent until impact with the water.

The pilot had received clearance into the approved airshow aerobatic airspace and initiated his first manoeuvre, a double snap roll. A video tape of the manoeuvre showed a deformation of the lower left wing within seconds of initiation of the manoeuvre which was followed by a failure of the left outboard portion of the upper wing. Both the failed lower left wing and the failed upper left outboard portion of the top wing, displaced aft against the empennage. The pilot had previously voiced his concern about the airplane's wings because of flutter he had experienced during recent flights. The National Transportation Safety Board determined the probable cause(s) of this accident as "the pilot's utilization of airspeeds greater than the manufacturer recommended manoeuvring airspeeds which exceed the design limits of the airplane and resulted in the subsequent failure of the wing spar". (NTSB: IAD96FA126).

One spectator commented: "I am no aerobatics expert but it looked as if there was a short pull-up, partial climb, and a couple of very messy snap-rolls. It was as if the airplane fell out of the loop and was out of control. After the second snap roll, the left wings failed structurally". Also mentioned in the TV coverage was that Speal's wife was narrating his demonstration over the event PA system at the time of the incident.

It bears remembering that most of the flying stresses on a biplane are upon the truss structure consisting of the set of flying wires, the wing attachment fittings, flying wire attachments, 'I' struts, cabanes/tripod, and less so on the internal complexities of the wing structure itself. Biplanes are immensely strong, despite very thin wings.

21 JULY 1996: DH98 MOSQUITO (BARTON, MANCHESTER, UK)

The fifty-one year old DH.98 Mosquito T.3 aircraft, based and maintained at British Aerospace's North Wales factory near Chester, crashed and its two crew were killed while displaying at a nearby airshow at Barton, Manchester, North West England. No spectators were hurt but it was reported that a number had to be treated for shock. The aircraft had performed a low-level pass and a pulled-up to about 1,000 feet agl for a wingover and appeared to stall at the apex, auto-rotating at least twice before entering a spin to the right. The pilot managed to recover but unfortunately, had insufficient height for the recovery pull-out. The aircraft struck the ground in a wings-level, nose-down attitude.

The aircraft (military serial RR299) was built in 1945, having just missed war service and was acquired by the Chester site in airworthy condition in 1963 for just £100. It had been maintained in flying condition and flown at air displays in Britain and Europe ever since. The aircraft was totally stripped down and refurbished in 1992 for that year's flying displays and it re-appeared in its usual grey/green camouflage but with the distinctive D-day black and white stripes added. Flying hours at the time of refurbishment were only 1,746. The aircraft was one of only two known airworthy Mosquitoes in the world, the other being Kermit Week's Mosquito B.35 bomber in the USA.

The best evidence of the event was derived from analysis of several video recordings obtained from members of the public. The display proceeded normally with steep turns and wingovers to the left and right being completed without evidence of any difficulty. The bank angle used during the steep turns was estimated to be 60° and the wingovers reached approximately 90°. On several of the fly-pasts, the speed of the aircraft was assessed by measuring the movement of the aircraft against background objects, frame by frame. These were not exact measurements but the results showed that the aircraft's groundspeeds were within the range of 220 to 240 kts. The speed during the final flypast was similarly assessed and, by repeating the process with several of the recordings, it was possible to say with a high degree of confidence that the groundspeed on this occasion was close to 240 kts. With the light crosswind at the time there would have been little difference between true airspeed and groundspeed. Without adequate background reference it was not possible to estimate the height and speed of the aircraft at the apex of the wingovers. The other pilot who shared the display flying on the Mosquito suggested that the airspeed would be 140 kts or more at the apex and eye-witnesses to the accident, estimated the height to be about 1,500 feet at the apex of the final wingover.

The video soundtrack of one of the recordings of the final flypast was subjected to a spectral analysis, which gave an RPM of 2,660, averaged for the two engines. This accords with typical engine RPM used for display flying of 2,600. The boost setting is assumed to have been selected to the usual value of around +7 psi. On one recording, the rotation of the propellers had been slowed by the strobe effect which resulted from the propeller blade passing frequency being a harmonic of the camera shutter speed. Calculations made on a frame-by-frame basis suggested that the left propeller was operating generally 20 to 40 RPM lower than the right which was not considered to be of any particular significance as there was no automatic propeller synchronisation system fitted to the aircraft.

The final part of the display was examined in greater detail. The aircraft flew from right to left along the display line at about 240 kts and entered a straight climb. During the initial climb the RPM of both propellers reduced slightly, probably as a function of reducing airspeed. The aircraft rolled to the right and the bank angle increased to about 90°. Shortly before the aircraft reached the apex of the 'wingover', the speed of the left propeller appeared to slow relative to the right and continued to slow until, at the apex, it appeared to stop completely. The roll continued until reaching an estimated 100° to 110°. The aircraft t hen yawed to the left and rapidly lost airspeed; the nose then pitched down, relative to the lateral axis and the aircraft began to fall. The bank angle reduced and the aircraft began to yaw to the left. There was little or no forward speed as the wings levelled and the aircraft nose pitched down violently. The aircraft then entered what appeared to be a spin to the left from which it recovered briefly before entering a spin to the right. Shortly before impact, the aircraft appeared to recover from the spin in a steep nose down attitude but this was followed by a violent yaw to the right from which it had insufficient height to recover.

The apparent slowing of the left propeller indicated only a change in RPM. However, the subsequent behaviour of the aircraft, namely the left yaw and the autorotative manoeuvre at low airspeed, was strongly indicative of an asymmetric condition caused by a large reduction of power from the left engine. It is thus probable that the observed RPM change was indeed a reduction. The fact that the right-hand propeller continued to rotate at the same speed was considered significant in that it suggested that the pilot was not making any adjustments to the engine controls at the time. Similarly, boost lever movement would initially result in an RPM excursion; this would be detected by the propeller control unit which would cause the blade pitch to alter such that the RPM returned to the selected value. It was therefore concluded that unless the pilot inexplicably reduced the power on the left engine, the observed propeller RPM change was symptomatic of a power loss.

On another video recording, a puff of smoke, with an accompanying 'bang' was apparent when the nose of the aircraft was pointing at the ground following the initial loss of control. It is believed that this puff of smoke came from the left engine although the evidence was not conclusive. This event may have been due to rapid throttle (boost lever) closure by the pilot as part of the recovery procedure, 'bangs' or 'crackles' being a characteristic engine response to such action. It is noteworthy that no smoke was visible from the left engine at the time of the observed propeller RPM reduction prior to the loss of control. This suggested that t-he cause of the propeller RPM reduction was not due to an excessively rich mixture. Most of the recordings showed the yaw to the right during the descent, as noted earlier. This could have been caused by a restoration of power on the left engine, and could explain the indications of symmetrical power at impact.

The pilot started flying in 1968 and qualified for a Private Pilot's Licence; in 1978 he gained an Airline Transport Pilots Licence. His main experience was on transport aircraft although he had flown about 529 hours on light aircraft. His first recorded flight in the Mosquito was in 1991. He flew it for sixteen hours in 1993, twenty hours in 1994 and twenty-seven hours in 1995. His first flight in 1996 was a display practice on 7 June. On 8 June he flew to Cranfield where he did two displays; his next flight, the last before the accident flight, was on 17 July. His total logged flying in the Mosquito in 1996, was 4:25 hours. (AAIB Bulletin No: 5/97 Ref: EW/C96/7/4 Category: 1.1)

14 JULY 1996: P-38 LIGHTING (DUXFORD FIGHTER COLLECTION, CAMBRIDGE, UK)

The Fighter Collection's P-38J Lightning crashed at the Flying Legends airshow at Duxford killing the pilot, "Hoof" Proudfoot. The massed displays of warbirds were memorable, all against a perfectly clear blue sky and 13,000 spectators. The P-38 Lightning was one of the stars of the show, executing high speed passes, loops and rolls-off-the-top but crashed during a sequence of consecutive aileron rolls, the final roll seemed to 'dish-out' for some reason with a slowing of the roll rate. The accident reduced the number of flyable P-38 Lightnings worldwide to six, however, with the restoration of "Glacier Girl", found in Greenland, this would restore the number to seven.

One spectator at the airshow expressed his concern and was a little disturbed by two manoeuvres, one was a high speed run towards the crowd and flight line following recovery from a wing-over; the second was a pair of aileron rolls along the line of the runway at very low altitude. "While expressing great sorrow for the loss of a unique historic aircraft and its pilot, it was fortunate that the Lightning did not veer left on impact, into the line of parked and irreplaceable WW II aircraft, and then into the crowd; as it was, wreckage destroyed light aircraft parked on the far side of the airfield", he said. A Chipmunk took a few knocks from debris, a PA-28 looked a write-off; most of the aircraft at that end were of the PA-28/C-172 variety - maybe six or so with varying amounts of damage.

Another concerned spectator commented: "I was there at Duxford on the Sunday and before the accident happened I was getting increasingly concerned at some of the flying going on. The guy in the Bf-109 was flying far too low. I would have given him a severe 'bollocking' afterwards if it was 'my' aircraft. I want to see these beautiful aircraft where they belong, in the air, not ploughing into the ground and if something good can come out of Sunday's sadness, then perhaps it will make some pilots treat these machines with a bit more respect and cut out the unnecessary risks".

In the ensuing discussion, further comment was made: "Bear in mind that Hoof was not only immensely experienced and the Fighter Collection's chief pilot - he was also the display director for both days. His safety briefings were an object lesson in crisp, to the point delivery. If the manoeuvres looked hairy, fine, but they would have been well rehearsed and complying with the strict CAA guidelines. Rod Dean was CAA observer on site on the day, Hoof knew that". His display line was south of the centreline due to departing P-51s. Even so, CAA rules on display lines are designed to greatly reduce the possibility of crowd line incursions of any sort, they are rigidly policed. This incident supported recent policy that nobody at Duxford was allowed to stay with their aircraft on the south side of the airfield. "I remember early 'Fighter Meets' where we picnicked under the wing with heavy metal pulling round right above our heads – exhilarating, but not so safe".

A P-38 expert who witnessed the accident was of the opinion that the elevator and rudder did not have inputs suggesting a slow-roll and went on to suggest that one of the MANY possibilities was that the aileron hydraulic booster pump failed, locking the ailerons into a roll. If that happened, the pilot would have to switch off the aileron boost (the switch is situated near the right rudder pedal inside the cockpit) and the whole situation at that point might not have been recoverable. That's not a theory on what happened, just a reality check to remind us that not everything that happens, is really human error.

There is no evidence to explain why the aircraft entered the second part of the final manoeuvre in a less than optimum pitch attitude which subsequently developed into a significant downward trajectory. The possibility of a temporary restriction to the flying controls, or some other form of distraction of the pilot, could not be dismissed. It was recounted that the pilot had been advised a day earlier that he had violated minimum height requirements in his aerobatic routine - executing an aileron roll in front of the crowd, although not by much. The 54-year old pilot was a highly experienced pilot with 14,500 flying hours of which 60 were on type; he had flown 11 hours on type in the last 90 days and 5 hours in the preceding 28 days.

One last comment from an aviation enthusiast: "The aircraft seemed to be pretty close to the ground to be performing continuous rolls, whatever, a fine pilot and a beautiful aircraft was lost. Each time his nose seemed a bit lower as he came out of it. At the end of the second roll it just flew into the ground, wing tip first. Low-level demonstration flying remains a dangerous business, no matter how much experience you have under your belt". (This accident is addressed in more detail in Chapter 4)

7 JULY 1996: DE HAVILLAND 112 VENOM (HAWARDEN AIRFIELD, BROUGHTON, CHESTER, UNITED KINGDOM)

The event was an Open Day and flying display at an aircraft manufacturing facility, organised by the airfield operator and approved by the CAA in accordance with the requirements laid down in CAA publication CAP 403. The 51-year old pilot held the required Display Authorisation from the CAA and had a total of 13, 233 hours of which nine were on type. Taking off from Runway 23 as the number four of a four-ship formation comprising two Vampires followed by two Venoms, the pairs departures in echelon starboard at 15 seconds intervals; the lead aircraft was positioned on the downwind side of the runway as is standard practice. The surface wind of 310° at 14 kts gusting 20 kts provided an eighty de gree crosswind from the right hand side.

The pilot stated that his lead aircraft's nose wheel had left the ground at the time of the 80 kts airspeed indicator check and he stated that both aircraft maintained a nose-up attitude until lift-off occurred. He said that after lift-off, his aircraft, G-VIDI, suffered a rapid right wing-drop which required a large opposite aileron input to correct. The aircraft then rolled rapidly left to a bank angle which the pilot estimated was 60°. Full righ t aileron and some right rudder application was necessary in order to stop the roll and reverse the direction.

The pilot assessed that the roll oscillation was becoming divergent and elected to land the aircraft back on the runway. However, the aircraft touched down on the left hand side of the runway centreline, initially on the right wing tip fuel tank, which ruptured; the aircraft yawed to the right and departed the runway to the left continuing along the grass and striking a displaced threshold marker light. The pilot applied the brakes and attempted to recover the aircraft towards the runway centreline, but the aircraft entered the runway and departed off the end, damaging the ILS Localiser antenna. When the pilot assessed that an overrun was likely, he attempted to raise the undercarriage, but could not operate the emergency retract system because of the violent ride.

The aircraft came to rest against the wire mesh perimeter fence just short of a public road running along the outside of the airfield boundary, some 100 metres to the right of the runway centreline. The pilot shut the engine down and switched off the electrics. He opened the canopy, released his harness and made safe the seat pan ejection seat handle. The airfield fire service arrived at the scene quickly and made safe the ejection seat top handle before removing the pilot to a waiting ambulance. Despite the rupture of the right wing tip fuel tank with consequent fuel spillage and impact with the airfield fuel storage installation, there was no fire.

Video tapes indicated that the nose landing gear of G-VIDI lifted off early and that the aircraft became airborne about three seconds before the lead aircraft's nose wheel had left the runway and the aircraft became airborne at a speed between 99 kts and 106 kts. The stalling speed of the aircraft in this takeoff configuration was estimated by the operator to be about 90 kts. The Aircraft Flight Manual Handling Notes, Take-off Section, notes that *"Care must be taken not to raise the nose too high during the take-off run as the aircraft may fail to accelerate"* and " *The aircraft should be flown off at about 110 kts at normal load and at about 120 kts at maximum load. Because of the possibility of a wing drop, the aircraft should not be pulled off the ground below the recommended speeds."*

The pilot stated that at no time during the sequence of events did the stall warning system operate (warning horn and light). The operator commented that, when the aircraft was inspected after the accident, the switch controlling the operation of the system was in the off position. It could not be determined if the switch had been on for the take-off. It was noted during the analysis of the video recordings that several other aircraft were experiencing the effects of turbulence and crosswind.

The airfield fuel storage installation dated from around the time of the Second World War and comprised two 10,000-gallon tanks used to store Jet A-1 turbine fuel. The airfield boundary fence comprised wire mesh netting supported by concrete posts which were not intended to be frangible in the event of an impact by an aircraft. Adjacent to, and outside the boundary fence, was a public road, the B5125. It was fortunate that the aircraft came to rest within the airfield boundary and did not cross the boundary onto the road from where some members of the public were observing the flying activities. (AAIB Bulletin No: 4/97 Ref: EW/C96/7/3)

19 JUNE 1996: MCDONNELL DOUGLAS F-18 (MCDONNELL DOUGLAS, ST LOUIS, USA)

McDonnell-Douglas test pilot, Jeff Crutchfield, was practicing aerobatics in a F/A-18 in Bethalto, Il, near St. Louis for the upcoming airshow at Fair St. Louis when his aircraft crashed into a residential area and exploded. The aircraft partially destroyed a home at the point of impact but the owners were fortunately not at home at the time. Jeff Crutchfield, the pilot, with over 6,000 flight hours, was killed. Witnesses said that the aircraft was on fire before the collision with the ground and it seemed that the pilot was attempting to avoid the homes in the last few seconds. According to McDonnell, the aircraft was relatively new off the assembly line, having been built four months earlier in February 1996.

Questions about whether the changes in McAir's assembly/maintenance could have contributed to the accident were subsequently raised in the *St. Louis Post-Dispatch* . The newspaper reported that seven machinists were interviewed who had said they had been doing complex repairs on an aircraft with the McAir manufacturing number C414 and that they had suspected that this was the aircraft that had crashed. A McDonnell-Douglas spokesman, Daryl Stephenson, later confirmed that the aircraft that crashed, was indeed C414.

Quoting directly from the *St. Louis Post-Dispatch* the machinists spoke on condition of anonymity because they feared retaliation from McDonnell Douglas. The machinists said they began repairing the aircraft in mid-May. "This aircraft had a history of fuel leaks out of one of its tanks," a machinist said. He and others were told to replace the No. 4 fuel cell, the largest of the multiple fuel tanks aboard an F-18. The work was complex and involved removing hundreds of tubes, clamps, electrical fittings and other parts to reach the rubber bladder that holds the aircraft's fuel. "It's like a crossword puzzle," said a machinist who had worked on the aircraft.

The maze of components regulate and deliver fuel to the aircraft's engines. So significant was the task of removing and replacing them, that the Federal Aviation Administration, in a document obtained by the Post-Dispatch, described the 4-month-old aircraft as 'rebuilt.' Mechanics must work in the fuel cell compartment, which is about four feet deep and so narrow that only a slender person can do the job. In all, enough components to fill three boxes, each three feet high, wide and long, were removed from the fuel cell before the machinists could reach and replace the fuel bladder. The machinists said they began putting the components back together as the June 5 strike action deadline drew near.

They said it is difficult to avoid damaging the components because of the cramped quarters of the fuel cell compartment. Some electrical components, for example, had dozens of wires and it was easy to dislodge them. "You can knock fuel lines loose, or you can knock a clamp off," said one machinist who had worked on C414. He said that could cause a fuel line to sever, cutting off fuel to one or both of the aircraft's engines. Some components supply the engines with fuel when the aircraft is inverted, as it was just before the crash. If these components malfunction, the machinists said, the engines would get no fuel. The machinists said much work, at least two full shifts by two experienced mechanics, remained to be done on aircraft C414 when the strike began on June 5. The machinists left their jobs for the picket line. McDonnell then began using supervisors and other white-collar employees to do work previously done by the machinists. Company spokesman Stephenson said white-collar employees completed unfinished repairs needed by aircraft C414. The machinists said white-collar employees did not have the skill needed to fix the fuel cell.

"Supervisors do not maintain the aircraft," one machinist said. "They do not know what we do." A machinist who worked on C414 said a supervisor who took his job had experience working on the aircraft, fifteen years ago. The supervisor could not be reached for comment. "It is difficult even for an experienced mechanic to finish fuel cell work begun by another person," the machinists said, "because the second mechanic cannot know for sure what the first had done". The machinists noted that witnesses heard the aircraft's engines make a popping noise just before the crash, the noise is typical of a jet engine starved for fuel.

One witness to the crash was Jim Crutchfield, the 18-year old son of Jeffrey Crutchfield, the late pilot. Jim Crutchfield had been a pilot for two years and was taught to fly by his father. As the aircraft plunged toward the ground, Jim Crutchfield said its engines made a clicking sound. He said it sounded line an engine deprived of fuel. "The engine lost power", he said. (1996, *St. Louis Post-Dispatch*)

Comment by a McDonnell Douglas colleague was that Crutchfield was one of the best engineering test pilots at McDonnell, and it was a real tragedy. This was soon followed by a counter opinion on an internet chat line on airshow safety: "No offence, but the history of airshow aviation is replete with 'The Best Pilots' overestimating their ability to 'push the envelope,' and dying for it. You simply DON'T DO IT! But they've gotten away with it a few times before and survived, and they develop the image of themselves, as something they're not, infallible - and they often pay for it with their lives. There was a B-58 'Hustler' slow roll at 150 feet one day at an Eglin AFB Fire Power Demo, and "I nearly crapped! Awesome!" Six months later at the Paris Airshow in 1961, another pilot tried a repeat and augured in right in front of everyone". "Airshows are great, but THEY CAN BE DANGEROUS".

26 MAY 1996: F-16/BAE SYSTEMS HAWK (PORTUGUESE AIR FORCE, BEJA AB, PORTUGAL)

Two fighter jets participating in the '96 *Tiger Meet* event at Beja Air Base, Portugal, collided in midair. A Portuguese Air Force F-16 and a Royal Air Force Hawk Trainer collided during a display flight. The British pilot ejected successfully and the Portuguese pilot managed to land his aircraft. Both pilots were uninjured and no collateral damage to spectators or the public occurred. Informed sources attributed this collision indirectly to inadequate briefing prior to an unauthorised display.

05 MAY 1996: HARVARD AT-6 (SERTOMA AIRSHOW, LOUISIANA, USA)

"It looked like the pilot stopped flying the aircraft halfway through the roll," commented a display pilot watching from the ground. It was Joe Hartung of Baton Rouge, a member of the Classic Jet Aircraft Association, owner of a Polish Iskra jet trainer, a B-25 and a T-6 Harvard who was killed while flying a low-level roll at the Sertoma Airshow. The aircraft crumpled when it struck the ground less than 150 yards from the stands where an estimated 13,000 people watched. Emergency crews arrived within one minute of the crash and the crowd was cleared from the stands about forty-five minutes later.

Careful study of the amateur video revealed that the first 'half-roll' to inverted was satisfactory, but then the nose dropped excessively. The roll continued to the right and the aircraft impacted the ground left wing low, but almost level, and upright. The first indication of an impending catastrophe was the excessive nose-drop while inverted with no down elevator applied to counter the nose-drop. There was no post-crash fire but the airframe was in pieces, albeit mainly large ones.

Anybody who has ever flown a T-6 will tell you about it's rolling performance and handling characteristics; it also doesn't have an inverted fuel/oil system – it is not fun at 1,000 feet, never mind at lower altitude. A T-6 is not an agile aerobatic aircraft and probably doesn't belong there doing low-level slow rolls. This is not the first T-6 that has dug a hole doing low-level aerobatics. A comment by an experienced display pilot: "I've done aerobatics in the T-6 at Kissimmee and I've always been puzzled as to why people would choose it as an aerobatic aircraft. It's a strong airframe, but heavy and ponderous, and yes, underpowered, even with that supercharged radial engine".

The pilot had many hours on type, and had his own T-6 which was in the shop. He had 11,000 hours total in almost everything imaginable. Wise old pilot say: “He who stalleth the T-6 close to ground shall surely perish”. Another wise old pilot says: “T-6 with low torque aileron bell cranks rolls like a PBY, even the B-25 has a better roll-rate”. More comment from an old T-6 ‘hand’: “I have over 3,000 hours in the beast, as an instructor and also did many low-level airshows. Airplanes don’t know which way is up, only the forces on them. By the way, you can fly inverted for a long time in a Harvard T-6 until the oil pressure gives out. I also have lots of negative-g time in the yellow peril”.

“I don’t personally know the pilot and I don’t mean to put him down in anyway,” said an experienced display pilot. “I have made the mistake he made doing his roll many times but I wasn’t at 50 feet. Anytime you are doing low-level aerobatics, you have to know what’s going on around you and you have to know how to make your airplane do what you want it to”. “I am not going to touch on any of the possible reasons that might have lead up to the accident, I’m just going to talk about the roll”.

“In any aircraft, it doesn’t matter how fast or slow it rolls, if you don’t control the pitch attitude, you’re going to lose altitude. That’s all there is to it. Obviously speed is going to help you and so will a faster roll rate, but if you can’t control the aircraft nose-position on the horizon, you will lose altitude. That’s why you really have to know the airplane that you are flying and what it is going to do. If you are low and inverted and you realize that you are going to dish out, stop the roll and push the nose up 10º to 20º and finish the roll. It doesn’t matter if the engine quits cause you should already have a lot of energy. It may look really stupid but hey, it beats hitting the ground”.

Some aircraft are harder to push above the horizon than others, the AT-6 happens to be one of them, but it’s something you have to know how to do. If you can’t do fifty good rolls without ‘dishing-out’ or ‘losing altitude’, then you really should think twice about doing it close to the ground.

16 APRIL 1996: HAWKER SEA FURY (SUN ‘N FUN, LAKELAND, FLORIDA, USA)

Charlie Hillard, 58, who together with Tom Poberezny and Gene Soucy thrilled airshow audiences for twenty-five years as the *Eagles Aerobatic Team* , was killed in an accident following a solo aerobatic performance at the Sun ‘n Fun EAA Fly-In at Lakeland, Fla. According to the NTSB report, the Hawker Sea Fury was landing after a display at the Sun ‘n Fun airshow. Hillard had made a wheel-landing and decelerated to a three-point attitude when suddenly, the tail lifted and the aircraft veered off the right side of Runway 27 at Lakeland Linder Airport.

The pilot suffered fatal injuries and the aircraft suffered substantial damage. Polk County (Fla.) Medical Examiner Alexander Melamud concluded Hillard died of “positional asphyxia” after “his chest and back were compressed by parts of the cockpit. He was asphyxiated when the big WWII-era British fighter came to rest inverted alongside the runway, crushing its canopy. Hillard had previously removed the roll cage from the cockpit to make room for a jump seat while restoring the aircraft for airshows. Hillard, had logged forty-two years and more than 15,000 hours of flight time. Some of his accomplishments included, member U.S. Skydiving Team 1958, National Aerobatic Champion 1967, World Aerobatic Champion 1972, Leader of the *Eagles Aerobatic Team* 1971-1995 and EAA Oshkosh airshow boss 1991-1995. While Hillard had relatively little Sea Fury experience, he had 250 hours in various warbirds and had logged 14,400 total hours during a long flying career that included 25 accident-free years with the famed *Eagles Aerobatic Team*. Hillard had purchased the Sea Fury and re-entered the airshow circuit in 1996 as a solo act after the *Eagles* had disbanded the previous year.

To spectators it looked like Charlie Hillard was about to set the tail down on the Sea Fury, when the tail suddenly rose very quickly and the aircraft yawed sharply to the right. It looked like a frozen brake because the tail whipped-up so fast that in about an eighth of a second, the aircraft flipped over on its back just off the runway. There was a lot of grey-white smoke emanating from the exhaust stacks as the aircraft veered right and departed the paved surface. The prop kicked up sand and dirt and dug into the ground as she went up and over, rather slowly, in fact. The aircraft was clearly supported by the vertical stabilizer and the cowling; the tail did not crumple and at the relatively low speed at which it flipped over, one would have expected the pilot to survive.

The NTSB ruled that ‘pilot error’, more particularly, “the pilot’s improper use of brakes and ailerons during the landing rollout with a right crosswind, killed Hillard; the combination resulted in a loss of directional control and subsequent nose-over”. The board listed the six-knot right crosswind, along with Hillard’s lack of experience in the Sea Fury (41 hours) as factors contributing to the accident. Videotape of the accident indicated that the left aileron and both elevator surfaces were up during the landing rollout and accident sequence. The NTSB also reported that the Sea Fury’s hydraulic system pressurized normally during a post-accident test of its brakes. Additionally, board investigators said they found no visible brake callipers leakage, and no abnormal wear on brake disks or linings. According to the NTSB’s factual report on the crash, mechanics had installed new brake pucks on both the left and right wheels just days before the accident. Hillard also had recently replaced the aircraft’s right wheel and brake calliper after a brake key came out of the wheel and became lodged between the wheel and calliper while the aircraft was being pushed into a hangar at Hillard’s home field in Texas.

NTSB investigators found skid marks indicating intermittent left main gear braking that started at the 5,000-foot runway marker and continued for 439 feet. At that point the left brake became continuous until the aircraft departed the runway. A continuous right main gear brake application began 400 feet further down the runway than where the left brake was first applied. Both left and right tire marks veered to the right.

Tom Poberezny, a fellow Eagles Team member and close personal friend of Hillard’s, said that he found it difficult to accept the NTSB’s conclusions. “I know, and others know, that putting an aircraft up on jacks and testing the brakes after an accident doesn’t mean they were working fine before,” he said. “I didn’t see it happen, and I know the NTSB did the best job they could with the time they had available,” Poberezny said. “I’m not criticizing the NTSB,” he emphasized, “but most causes of accidents aren’t black and white”. “I flew with Charlie for twenty-five years,” Poberezny said, “and I have a hard time accepting pilot error”. On the other hand, he added, “I can’t totally dismiss it, either”. “I’m not sure we’ll ever know what caused this accident, but I know one thing for sure,” Poberezny said, “my opinion of Charlie as a pilot hasn’t changed. “He was a superb airman.” (Orlando Sentinel, 4/17).

8 NOVEMBER 1995: PILATUS PC-7 MKII ASTRA (SAAF, LANGEBAANWEG, SOUTH AFRICA)

Two flight instructors of the South African Air Force, Capts. Weston and Dormehl at the CFS Langebaanweg and members of the newly formed ‘ *Astra Aerobatics Team* ’ were authorised for formation aerobatics practice for an upcoming show. After finishing the first sequence successfully, during the second manoeuvre of the second sequence, the formation had completed the barrel roll to the left in the ‘Star Formation’ when No. 6, Capt Dormehl moved out to the right and upward and in the process, bumped the No. 2 aircraft on the left side of the vertical stabiliser with sufficient force to cause significant structural damage. Capt Weston, having difficulty in maintaining control, ejected successfully shortly thereafter, while Capt Dormehl completed a low speed handling check prior to landing uneventfully.

27 SEPTEMBER 1995: B-26 MARAUDER (CAF, TEXAS, USA)

The world’s only airworthy B-26 crashed outside of Odessa, Texas; the aircraft was completely destroyed and all five on-board, two pilots, one crewmember and two passengers, were killed. The WW II vintage bomber which was based at the Confederate Air Force in Midland, Texas, was purchased by the CAF in 1968 and started flying in 1984. The victims were identified as Walter Wootoon, Vernor Thorp (a charter member of the CAF), John Cloyd and two British citizens. The two passengers from the UK were reported as Chris Gardner and Colin Dunwell, aviation enthusiasts.

Just a routine practice flight for the airshow, five miles south of the airport, both engines were heard to be “spluttering” and were apparently both shutdown. Although they made a safe forced landing, the aircraft ran into an ‘above ground’ gas pipeline which resulted in a large explosion. Despite the accident, the CAF airshow continued as scheduled.

2 SEPTEMBER 1995: BAE NIMROD (RAF, CANADIAN NATIONAL EXHIBITION AIRSHOW , TORONTO, CANADA)

Silent disbelief paralysed the more than 100,000 spectators crowded along the shoreline during the Canadian National Exhibition (CNE) as the four-engined RAF Nimrod disappeared into the water of Lake Ontario, Toronto, while performing at the airshow. The Nimrod was demonstrating its ability to avoid heat-seeking missiles when it crashed while pulling-out from a low-level wing-over, hitting the water at approximately 230 mph., killing all seven crew members. The final move of the sequence was a steep pull-up, fire the flares, and then a steep left turn away from the show line simulating missile evasion tactics. Rescue boats and helicopters were on the scene within minutes and life jackets were seen amongst the flotsam.

The video showed the aircraft diving down in what looked like a 25º nose-down, wings level, attitude at approximately 700 feet and descending rapidly. The pitch attitude increased very briefly followed by an almost immediate stall break at about 500 ft or less, and a continued descent into the water with little change in descent angle. It would seem that the pilot realized that the way things were going, they were going to hit the water, and pulled hard to try to prevent it.

Comment from a learned ex-RAF pilot who watched through binoculars as the four-engined jet sent up a shower of spray and debris: “It was an almighty splash and then, a few seconds later, a big bang. It was almost as though it just disintegrated,” he said. He went on to say that; “The Nimrod stalled, simple human error, all four engines were operating when it crashed. High angles of bank plus g equals higher stalling speed, all pilots know that and the speed went too low. Right before it crashed, there was complete silence. Then it happened, then the complete silence again. It was almost like it was preordained.” Whatever the cause, the end result was very disturbing; they had flown the same routine in Shearwater, Nova Scotia. The crowd reacted in horror, mothers hid the faces of their children, and others wept openly”.

Air Vice Marshall Peter Squire of the Royal Air Force said the crewmembers, based in Kinloss, Scotland, were veteran airshow performers. “This was an experienced crew that had performed similar demonstrations at a number of airshows this year. We are deeply saddened by what has happened to this crew,” Squire said. The aircraft, usually used for maritime reconnaissance and anti-submarine patrols, was performing a manoeuvre known as a wingover when it crashed. The Nimrod was demonstrating its ability to avoid heat-seeking missiles by pulling up into a climb, followed by a steep turn and dive. “It did not recover from the dive,” said Squire.

Airshow president Don Chapman said the show was suspended until the crash investigation was completed. He said the Nimrod appeared to be within Federal safety rules at the time of the crash, which required the plane to be at least 1,500 metres from all spectators. A Metropolitan Toronto councillor, said the exhibition should reconsider hosting the airshow in the future.

Yet, another question raised: “However well practiced, something went wrong, what was the pilot using for his altitude reference during that final manoeuvre, was it his RADAR altimeter? His barometric altimeter? Was it set to QFE, or QNH? QNH is used in Canada, if the pilot had QNH set and was used to using QFE and ‘forgot’ that small fact, then he would have been roughly 350 feet, the elevation of Lake Ontario, lower at the top of his climb than he would have been completing the same move over the ocean, or if he had set QFE (assuming a barometric altitude reference). It is doubtful if the RADALT would be a useful as an accurate reference at the bank/pitch angles that were flown. Likewise, the view out the front windows would be equally dubious to measure the aircraft ground clearance, much more difficult over water surfaces.”

Another big RAF jet that suffered a similar trajectory and fate was the airshow crash of a Vulcan B2 of 617 Sqdn on 11 August 1978. The aircraft stalled during a wing-over at an air display rehearsal at NAS Glenview,Chicago, Illinois USA and crashed into a nearby rubbish tip adjacent to the airfield, fortunately, also without inflicting collateral damage.

Airshow crashes over water surfaces have traditionally raised the question; “Are airshows more dangerous over water surfaces?” Although there is no scientific statistical information to substantiate or dispel such theories, the total number of accidents at the CNE airshow are 8 crashes in 53 years with 16 deaths. The accidents occurred as follows:

1949 - RCN aircraft, 2 fatal.
1953 - RCAF CF-86, 1 fatal.
1957 - RCAF CF-100, 2 fatal.
1966 - USN Blue Angel, 1 fatal.
1976 - Vintage DH Tigermoth, 1 fatal.
1977 - Vintage Fairey Firefly, 1 fatal.
1989 - 2 CAF Snowbirds, 1 fatal, 1 safe ejection.
1995 - RAF Nimrod, 7 fatal.

9 SEPTEMBER 1995: MESSERSCHMITT BF-108 (BERLIN, GERMANY)

The German science astronaut Reinhard Furrer, 54, guest-of-honour at the final Johannistal Airshow, died together with 39-year-old pilot Gerd Kahdemann in the debris of a 50 year-old, Messerschmitt 108 'Taifun'. The physicist had been launched into space on board the U.S. space shuttle 'Challenger' almost exactly ten years previously where he had conducted scientific experiments during the 'Spacelab' mission. The airshow was being presented for the last time at the historic site southeast of Berlin where the pioneer of German aeronautics, Otto Lilienthal, had conducted his first flying attempts. The site was due to be redeveloped into a business area.

During the afternoon, the single-engined propeller aircraft had taken part in the show programme with other historic flying machines at the former airport Johannisthal. The show already had closed when Furrer and the pilot decided to fly a few more passes over the fairground. An eye-witness described the disaster on Saturday shortly after 6 p.m.: "They were flying two rolls in succession, then attempting a third roll - at that point, one of the wings touched the ground and the aircraft burst into flames". Others reported that the aircraft quickly lost height after a roll, the nose dropping excessively and scooping before finally crashing in a steep descent. Fortunately there were no spectator casualties even though the aircraft crashed only 500 metres away from the nearest group, impacting the ground in the fields near the landing strip. The fire brigade and an ADAC emergency helicopter arrived at the scene almost immediately, however, Furrer and Kahdemann had no survival chance. Despite the accident, the airshow continued on Sunday as a tribute to the pilots and crewmembers.

The Messerschmitt 108 'Taifun', was the basic aerodynamic model of the modern touring class aircraft. In 1933, Messerschmitt received the order to build an aircraft for a trip around Europe in 1934. The Bf-108, also called Me-108, was far ahead of its time, winning many international competitions and in July 1939, the aircraft flew to a record altitude of 9,075 metres. This particular aircraft was one of only two aircraft of its kind in the world, the other one being owned by Lufthansa. The Bf-108 was not certified for aerobatics "There are old pilots! There are bold pilots! "But there are no old, bold pilots". Flying had been his life, now the astronaut found his death in a historic plane that he was not even flying himself.

17 JULY 1995: AERO L-39 ALBATROSS (SLOVAK AIR FORCE, *WHITE ALABRATROSS* AEROBATIC TEAM, SLOVAKIA)

The '*Biele Albatrosy'* team had already received international acclaim and requests for performances consequently increased significantly, 1995 being a particularly busy show programme. During a display practice, a collision between Albatrosses No. 2 and No. 6. resulted in the pilots Lt Col Ing. Marian Sakac and Captain Ing. Robert Rozenberg (pilot-in-training) ejecting. Major Ing. Peter Fianta landed safely with a damaged aircraft.

24 JUNE 1994: BOEING B-52 (USAF, WASHINGTON STATE, USA)

At about 2 p.m. on 24 June 1994, a B-52 bomber took off from Fairchild Air Force Base in Washington State to practice a display routine for the upcoming airshow. Barely fifteen minutes later, it crashed at 170 mph, killing all four crew members on board and narrowly missing nuclear weapons bunkers and a crowded airmen's school. The aircraft was making a left-hand steep turn around the airfield trying to stay within the confines of the base, which for a B-52, required a pretty tight turn. The pilot had violated well-known restrictions just by flying over the area - all the flight publications stipulated: "circling south of runway 05-23 is NOT authorized" and was prohibited for a variety of reasons. A left turn would take an aircraft directly over the town of Medical Lake while low and slow with two fair-sized hills located two miles south of the end of the runway. The weapons storage area was also south of the runway with interference by nearby (4 miles) Spokane International's arrivals/departures being the main reason.

The bomber had just completed its downwind leg and was turning base-leg. Unfortunately, the surface wind was gusting 20 kts which added a significant crosswind component to the turn. The base turn actually took the aircraft downwind into the prohibited area forcing the pilot to have to turn even tighter. In a frame-by-frame replay of the accident video, the ailerons were kept in a 'left bank' position despite the fact that the B-52 was already at about 60º-bank angle. It was clear that NO recovery was initiated before the aircraft reached an EXTREME left wing down attitude, the descent to impact was so rapid that the bank angle seemed not to change at all from the beginning of the sequence to the end. The wingtip touched the ground at which point the entire aircraft just smashed into the ground, exploding in a massive fireball.

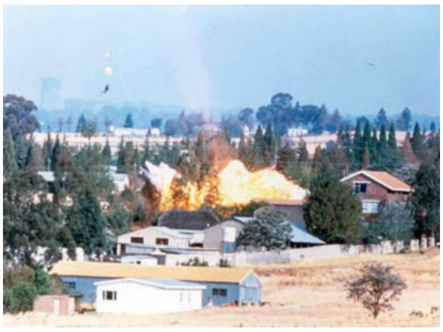
It appeared as if the engines were idled prior to the crash since no smoke could be seen being emitted from the engines. The crew did not 'punch out' because of the combination of low height and the large angle of bank of the aircraft; in fact, the crew most probably did not realise that they were in trouble until it was too late. It all just happened very fast, as most accidents do. A spectator commented that: "It looked like a classic loss of control accident but I just can't believe that trained military pilots would get themselves into that situation".

Video footage revealed that the co-pilot had tried to eject during the final spiral descent prior to impacting with the ground but he was unfortunately outside the ejection seat envelope and died impacting the ground before his chute could open; the ejection minima's for the upper deck of a B-52 are 90 knots and 0 feet agl. They had the speed, but the downward vector of the aircraft when he ejected, was what killed him. If he had a little more height, or level flight, he could have made it.

What was particularly alarming was that apparently, no one had wanted to fly with the pilot, Lieut. Colonel Arthur Holland, a veteran pilot with twenty-four years service about to retire from active Service. Indeed, two of the three other officers killed with Holland, were there because their subordinates feared flying with him. Holland had a reputation as a 'hot stick', he apparently once climbed the aircraft so steeply that fuel flowed from the vent holes on top of the B-52's wing tanks. His hard flying in one airshow reportedly popped 500 rivets during a prohibited climb and he apparently once put the B-52 into a 'tight spiral' over one of his daughter's high school softball games. One co-pilot complained that he had to wrestle control from Holland, who cleared a ridgeline by only a few feet during a run three months previously. Most ominously, junior crewmembers said Holland had often talked about 'rolling' a B-52 in flight, something that had never been done before.

Yet Holland's superiors put him in charge of evaluating all B-52 pilots at the base and while thirteen previous commanders allowed him to keep flying, only one, on assignment for barely a year and never warned by his predecessors of

Holland's reputation, was court-martialled over the crash. He pleaded guilty. The commentary by a CBS local affiliate was that the crew were practicing for an upcoming airshow and that the aircraft commander may have been 'hot dogging'. They went on to say that after a previous airshow, the same pilot came back with rivets popped on his B-52. If this was true, this pilot had a history of stretching the limits of the aircraft, and using questionable judgement. The report included two shots, one, a B-52 approaching a ridge at about 30 ft and pulling up at the last second. In another shot, he did the same manoeuvre, except approaching the camera directly. At one point, the camera was almost looking down on the B-52 before it pulled up. This was a tragedy because the air force had other officers complaining about this pilot's 'hotrodding'. CBS said that there was something like ten superior officers who, over the course of years, could have grounded this pilot and didn't.



Catastrophic wing failure due to poor maintenance configuration manage-ment. (SAAF Directorate Flying Safety)

CBS said that the co-pilot Lt. Col. Mark McGeehan, who died, had become so frustrated that he would let no one else fly with Holland. McGeehan was the squadron commander and had requested that the pilot be grounded, but the wing commander refused his request. After that point, he volunteered to be the only one to have to fly with Holland, so that other's lives wouldn't be endangered. The tragedy could easily have been far worse. The crash occurred not far from the Survival School and about 500 people were outside for a picnic, many said they could feel the heat from the fireball. Had it occurred inside, the cleanup would be more difficult by a few orders of magnitude. Another, possibly worse scenario, would have been if the aircraft had crashed in the weapons storage area, perhaps causing a radiological nightmare.

In a similar "heavy" crash at Fairchild in the 1986-1987 time frame, a KC-135 crashed in an open area on the base itself, coming to within 50 yards of the base operations building. The tanker and another B-52 were practicing displays for an airshow when the KC-135 encountered the B-52's wake turbulence and crashed, illustrating the problem of doing extreme manoeuvres in large aircraft while near the ground. Maybe now someone will realize you don't yank large aircraft around near the ground just for fun?

14 FEBRUARY 1994: F-16C (USAF *THUNDERBIRDS*, NEVADA, USA)

The pilot of an F-16C, Capt. Lewis of the USAF *Thunderbirds*, was performing a spiral descent and did "one too many" downline spirals. It was a low recovery from which he thought he could pull out and basically 'slid' across the desert floor at the bottom of the pullout. He did not eject but was fortunate to survive the crash; the jet remained intact but the pilot suffered back and leg injuries. He recovered fully to fly the F-16 again...but, never as a *Thunderbird*.

2 OCTOBER 1993: AERMACCHI MB-326 (SAAF, *SILVER FALCONS* AEROBATIC TEAM, SOUTH AFRICA)

One of the highlights of the Africa Aerospace 1993 was the display by the South African Air Force's *Silver Falcons* aerobatic team. Flying the Italian jet trainer, the Aermacchi MB-326 'Impala', the singleton crashed killing the pilot, Capt Charles Rudnick.

The four-ship diamond was performing a barrel roll synchronised with the singleton's loop. On pulling out from the loop and with the nose at approximately 45° below the horizon, the right-hand wing of the Impala failed catastrophically sending the Impala out of control at approximately 300 ft agl. The fuselage continued downwards and completed two and a half rolls before impacting the ground. The pilot ejected after approximately two rolls and the left wing separated from the aircraft, just prior to impact. The combination of the centrifugal forces of the auto-rotating Impala, the extreme attitude of ejection and the low height, gave the pilot no chance of survival. The pilot's semi-inflated cute impacted on the fringe of the post crash fireball.

The aircraft landed in a built-up area on the boundary of the airfield but miraculously, no spectators or members of the public were injured although debris from the wreckage caused collateral damage to surrounding infrastructure. The cause of the catastrophic separation of the wing was a fatigue crack in the wing centre section lower beam, which caused the failure of the centre section. The failure to repair an earlier crack in the wing main spar during scheduled overhaul was determined as the primary cause. This failure was not detected in the configuration control management at the maintenance and overhaul facility.

A fleet modification required a centre section modification to increase resistance to fatigue crack formation and a fatigue life-monitoring programme was put in place for the Impala fleet. As an unmodified airframe, this aircraft disappeared from the monitoring graphs but reappeared 2½ years later as a modified aircraft. Physical inspection revealed that the actual modification had never been carried out and investigation revealed that the airframe had flown 1,593 hours beyond its calculated fatigue life.

08 AUGUST 1993: SAAB JAS-39 GRIPEN (SWEDISH AIR FORCE, STOCKHOLM, SWEDEN)

The final report of the Swedish Aircraft Accident Investigation Board's investigation on the Gripen crash in Stockholm on 8 August 1993 recorded that the crash sequence had started with a low speed 360º left turn at 280 metres agl. The afterburner was lit, speed 285 km/h, load 2g, bank angle 65º and angle of attack 21º. Rolling out of the turn, the control stick was moved to the right almost to the endpoint and slightly forward. The left aileron control surface rapidly travelled to the bottom position. The aircraft banked 20º to the right and the angle of attack decreased to less than 10º. In order to quickly regain a wings level attitude, the pilot rapidly pushed the stick almost all the way to the left and continued to keep it slightly forward. This caused the control surfaces to move at their maximum deflection speed, and since the flight control system then had little or no control surface displacement available on its own to work with, the stability margin was reduced. The pilot entered into a Pilot Induced Oscillation (PIO), the same phenomenon that brought down the YF-22 during its early development.

In technical terms, during the low speed left turn, the automatic roll trim disconnected, exactly as automatically intended to at angles of attack exceeding 20º AOA but because of this, the control stick had to be kept 2º over to the right in order to maintain constant bank angle. The stick movement to the right to roll out of the turn was the same as during training, but as it was initiated from 2º to the right already, it easily reached the geometrical stop, leading to a larger roll rate than the pilot anticipated.

It was known to the flight test authorities that this could happen but they had estimated that the probability of this happening in flight was negligible. The oscillation diverged and the aircraft pitched-up on its tail, nearly instantaneously lost all forward speed and departed out of control. The pilot could not do anything to recover or even steer it away from the thousands of spectators and took the only available option, he ejected. By a remarkable and extremely fortunate coincidence, the aircraft crashed in an area in which there were no spectators, saving a re-run of the Ramstein accident.

The accident investigation board ruled that the aircraft had been in good working order and that a combination of the pilot's harsh stick movements, along with the flight control system automatic levelling, caused the accident. In the crash, the flight control computer was severely damaged, but all pieces were recovered and all memory circuits identified, which allowed the information to be read, so full data from the whole crash sequence was available to the investigators.

More significantly, however, the way the display was planned was not in accordance the goals stated for the flight test programme nor were any reasons advanced for the exceptions made from the Pilot's Handling Notes. Although the flight limits set for the display were exceeded by the pilot, this did not contribute directly to the accident. The control laws are complex, which meant that there were problems to fully analyse their function. Surprisingly, the effects of control surface deflection speed limitations had not yet been fully investigated throughout the full flight envelope and therefore, the validation process by the Manufacturer hadn't successfully identified the pilot induced oscillation properties of the aircraft. When flying the simulator, less work with the control stick was needed than when actually flying. Simulator studies showed that it was possible to stall Gripen at less than 20º angle of attack during similar conditions.

In all fairness though, there is no flight test programme that can guarantee that the entire spectrum of aircraft behaviour has been characterised, especially something as sophisticated and complex as a computerised flight control system, particularly the PIO. The question that must be asked is: "to what extent an aircraft under development can be demonstrated to spectators"; put another way, what recourse would spectators have to make claims against the manufacturer in the event that spectators were killed or seriously injured? What risk analysis was done by the manufacturer prior to releasing the aircraft for demonstration purposes? Was the 'reasonable man' argument adequately applied?

The reasons for the crash can be best summed up within the realms of pilot's commands, control stick properties, control law limitations and control surface limitations. Contributory reasons included the fact that this series aircraft differed from the prototypes in ways the pilot was not apparently, fully briefed on. The aircraft was lighter, which as well as providing a higher thrust/weight ratio made the aircraft slightly more sensitive in pitch. The control stick required lower input forces and could generate a larger roll output, resulting in higher available roll rates. The mass distribution was also slightly different, which required the control stick to be kept 2º to the right to maintain constant bank angle when the automatic roll trim system disconnected.

The flight control system, the engine and all other systems worked as advertised until the aircraft impacted and no external cause was suspected. The pilot was properly trained and equipped and although the limits for minimum altitude and maximum angle of attack were exceeded marginally, it had little bearing on the cause of the crash. The manufacturer and customer knew that large and rapid stick movements could cause divergent Pilot Induced Oscillations, but considered the probability of it actually happening as insignificant, so all pilots were not fully informed. Lastly, the warning light informing the pilot that the control system was saturated, activated too late for the pilot to do anything about it. Nearly simultaneously, the pilot no longer recognized the aircraft's behaviour and the low altitude of 270 metres, made it literally impossible for the pilot to attempt to regain control.

24 JULY 1993: MIG-29 (RIAT '93, RAF FAIRFORD, UK)

Two Russian test pilots amazingly escaped with only minor injuries following ejections at low-level from their Mikoyan MiG-29s after colliding during synchronised aerobatics at the Royal International Air Tattoo 93. The two MiGs from the Russian Flight Research Institute at Zhukovsky near Moscow, were flown by civilian test pilots, Sergey Tresvyatsky and Alexander Beschastnov who suffered only minor injuries during the low-level ejections. No one amongst the thousands of spectators was hurt although some were treated for shock.

The fighters collided as Tresvyatsky was pulling out of the loop and Beschastnov's aircraft pulled up across his path. As a result of the impact, Tresvyatsky's aircraft was sliced through just aft of the cockpit and exploded into a fireball just seconds before he ejected. The blazing aircraft crashed behind the flying display aircraft parking area across the runway, a short distance from the crowds. Beschastnov also ejected immediately following impact as his aircraft lost control when a section of its left wing was severed. What remained of his wing was ablaze as his aircraft plunged to the ground, crashing into a field about a mile northeast of the base.

To the spectators, the display was characterised by a high number of head-on passes, the aim of which was to impress and in most cases, excite the spectators using speed and timing. They were doing a synchronous loop and both pulled up into the light cloud cover, but on exiting the cloud, the No. 2 aircraft was ahead of the lead aircraft. Since the lead was looking backwards to see where No. 2 was, and No. 2 was looking ahead trying to visually pick-up the leader, situational awareness was lost when they did not have one another visual.

The lead aircraft broke into a left hand turn away from the crowd, colliding with No. 2 who was now directly in front of the lead aircraft. They apparently called 'lost visual' on the radio but they didn't get any reply from the safety pilot because the safety pilot was in a parked Tu-134 and apparently had no power and so he wasn't able to reply. Lead's aircraft started to roll and he ejected two seconds after the impact while No. 2 ejected three seconds after impact. One of the lesser-known facts of this accident was that the two MiGs were actually carrying out the "lost-contact" procedure when they collided with one another.

Rescue helicopters took off within seconds of the crash. The one MiG crashed some way outside the airfield while the other 'impacted' just outside the boundary fence within yards of a Belgian Air Force C-130. One ejection seat came down on the centreline of a taxiway between the parked *Red Arrows* display team and an Italian Air Force G-222. Somewhat surprisingly, only minor damage was caused on the ground, the Belgian C-130 suffered damage to its rear tail section and the Italian G222, to its main fuselage (*Air Forces Monthly* January 1995)

Commentary stopped for a while, but when it returned, it was evident from the commentator's voice that he was shaken. He told the crowd that what they had seen wasn't supposed to have happened and that rescue services were on the way. Generally, the crowd was concerned about the safety of the pilots and collateral injuries but strangely enough though, there were also some spectators, realising the full impact of what had just happened, who were more concerned about whether they had captured the accident on film!

To the amazement of the spectators, the airshow just continued, the next display almost directly after the accident with hardly any delay whatsoever. This may be standard practise at some air displays but it seemed a bit odd to the spectators, the show just continued as if nothing had happened. Spectators reported surprisingly low levels of explosive noise which one would have expected from the energy release at impact. Most people around had no idea what had happened to the other MiG as everybody followed the fireball, and then they saw the other parachute.

In the words of one of the spectators: "Then they started to do opposing moves, and all of a sudden, one of the MiG's just burst into a huge fireball, you could hear the whole crowd gasping in amazement. I couldn't tell that they had actually crashed into each other and just thought that something went wrong with the jet. I don't think most people knew that they had crashed at the time. It all happened very quickly, I was following the flaming MiG as it crashed to the ground, and when I looked up at the sky, I could only see one parachute floating in the air, not having seen the pilot ejecting".

It was truly miraculous that both pilots survived with no major injuries to aircrew or spectators, the only injury rumoured was that to the pilots resulting from a punch thrown between the two of them in the ensuing argument to apportion blame.

26 JUNE 1993: BOEING PT-17 (*STEARMAN BI-PLANE WINGWALKING TEAM* , CONCORD INTERNATIONAL AIR FESTIVAL, USA)

A fatal crash occurred at the Concord (NH) International Air Festival. The performances had included 'fly-bys' of F-117A, KC-135, A-10's, a parachute show by the Golden Knights in the morning, followed by a schedule of aerobatic and stunt flying in the afternoon. The third afternoon performance was to be a wing walking stunt flight by Ron Shelly and his daughter Karen from Midland, Virginia. Flying a PT-17 Stearman bi-plane with pilot Ron in the back seat, the flight was being conducted under Title 14 CFR 91.

The initial portion of the performance was according to script, consisting of a take-off, snap roll, vertical hammerhead and low pass at about 100 ft agl. Both Ron and Karen were seated at this point and Karen was scheduled to climb up on top of the upper wing for a 'wing-walk' later in the show. After completing the roll left, the aircraft continued rolling from which it did not recover prior to impacting the terrain.

Mr. Wayne T. Smith, Aviation Safety Inspector (Operations) for the Federal Aviation Administration, was the Inspector-In-Charge for this airshow and he witnessed the accident. In his report, Mr. Smith stated: "I observed the acrobatic performance and accident from the airshow command platform located at the show centre. After the aircraft completed a left slow roll, it entered a left snap roll. I saw the aircraft lose approximately 50 to 75 feet after completing three quarters of the roll. I could see from the acrobatic smoke that the aircraft was skidding to the right. The aircraft continued its left roll as its wings came level at about 25 feet above the ground. The nose then pitched-up sharply while the aircraft continued its roll to the left. I could still hear the aircraft engine and it sounded normal to me. The nose of the aircraft continued smoothly in its arc while the wings continued to roll to the left. The nose came down through the horizon striking the ground at about a 60º attitude, the left wing struck the ground almost at the same time and almost immediately thereafter, the aircraft erupted in flames".

The fire engine reached the aircraft within a minute but it took several minutes to extinguish enough of the fire to get close to the occupants. Initially spectators thought the airshow would continue after securing the accident, but one by one the acts were cancelled and the airshow was eventually terminated for the day. The airshow on Sunday was repeated and dedicated to the memories of Ron and Karen. The pilot had reportedly told the airshow manager that he wasn't feeling well and was planning to cut short part of the airshow. This was reported in the Washington Post, which ran it for local interest since the performers were Washington area residents. The National Transportation Safety Board determined the probable cause(s) of this accident as follows. "Loss of Airplane Control as the Result of Incapacitation".

2 MAY 1993: NORTH AMERICAN F-86 SABRE (EL-TORO AIRSHOW, CALIFORNIA, USA)

NBC Radio News reported the first major airshow crash of the '93 season, an F-86 Korean era jet fighter, crashed at the El Toro Marine Corps Air Station "Open House" in southern California. The aircraft was pulling out of a loop but there was insufficient height to complete the loop; the aircraft crashed on the runway, exploded and the flaming wreck simply slid along the runway. The aircraft impacted almost dead centre on runway 34 Left, the debris spread out 5,000 feet along the runway with the spectator line a couple of hundred yards from the runway. There was a hour and a half delay as the show organisers cleaned up the runway, then the show resumed with an AV-8B Harrier, a civilian act, and the *Thunderbirds* ; the other pilots apparently voted that the dead pilot would have wanted it that way. They didn't announce that the pilot was dead until the end of the show. For witnesses to the F/A-18 crash five years previously at the El Toro Airshow, it seemed to be the same manoeuvre; it was a nasty 'deja vu'. CNN reported that over 1,000,000 people attended the airshow during the three-day event.

Witnesses said that the pilot began that final loop from too low of an altitude which was also probably the cause of the crash, not mechanical failure or any other Medium-induced factors. Several knowledgeable observers said he didn't have enough speed going into the loop and from the video footage analysis, it was obvious that the aircraft was stalled just before it hit, but that's because the pilot knew he had run out of height and just 'yanked' back on the stick. It appeared that the Sabre was going to make it successfully through the bottom of the loop then the nose dipped just as it crashed. Perhaps an accelerated stall?

In the LA Times the next day, it was reported that the F-86 was originally supposed to do a mock dogfight against a restored MiG-17. The MiG, however, developed mechanical problems on the day of the show and was unable to fly. The F-86 pilot then elected to support the programme by means of a solo display that the pilot had apparently practiced on the previous day for the dress rehearsal as part of a 'stock' routine for this kind of occurrence. One of the local TV news reported on the Sunday that the 'other' pilot had an ear infection, thus couldn't fly.

James Gregory had flown the Sabre nineteen times in the last sixteen days. T.J. Brown, listed on the programme as being the F-86 pilot, was also a pilot of the Coke/Holiday Inn 4-Pitts team, was shown on a TV interview saying that he knew the F-86 was in trouble at the top of the loop as it appeared to "not have the right parameters" of speed and altitude to make it.

The 'anoraks' monitored the air traffic control tower and crash crew frequencies after the crash, for about an hour. They heard the post crash management control proceedings, from the crash rescuer crews finding the pilot and requesting paramedics, to the 'General' wanting to continue the show if at all possible. From the "FAA en-route and don't move anything" to a request to send the doctor to treat family members of the pilot The mood was very sombre until the show was restarted, being dedicated to the pilot of the F-86.

There had been two other crashes in the previous eight years at El Toro. According to KFWB the local news radio, in '85 a WW II vintage aircraft crashed into a vacant church on the base and the two occupants were killed. In '88, an F-18 crashed at the bottom of a loop, seriously injuring the pilot as the aircraft 'mushed' into the ground. (This accident is discussed in more details in Chapter 4)

23 JANUARY, 1990: MCDONNELL DOUGLAS F/A-18 HORNET (USN *BLUE ANGELS,* EL CENTRO, CALIFORNIA, USA)

A *Blue Angels* pilot, Marine Capt. Chase Moseley, in only his second month flying with the team, escaped with minor injuries after his F/A-18 Hornet collided in mid-air with the *Blue Angels* flight leader and commanding officer, Cmdr. Pat Moneymaker, 43, during a training flight. The $18 million aircraft was destroyed. The jets collided over the desert in a desolate uninhabited area of the Naval Aerial Gunnery Range near the Superstition Mountains; the gunnery range is one of two locations near the El Centro Naval Air Facility in the Imperial Valley where the *Blue Angels* train from January through their first show in March. Weather was not a factor and the *Blue Angels* season was not affected by the accident.

Moseley was flying No. 2 on the right, slightly low and to the rear of Moneymaker in the team's diamond formation on a training flight. Shortly after Moseley positioned the aircraft, he noticed his aircraft was oscillating up and down and his attempts to smooth the motion only seemed to aggravate this pilot induced motion. He radioed: "Chase (his call sign) is clear," but as he attempted to clear the formation, he realized that his aircraft was too close to Moneymaker's. The two aircraft locked together for a moment as they collided and then his aircraft suddenly rolled further left to about 150º left bank, headed down at about 20º to 30º, Moseley said. Sitting inverted seeing the desert through his canopy and not getting a response from his aircraft, Moseley ejected and was picked up by a search and rescue helicopter from El Centro Regional Medical Centre. After the ejection, Moseley's aircraft flew inverted for a while before the left wing fell off and crashed on federal land near the base.

The accident happened during the first of three 'fan breaks' designed to have four aircraft in a diamond formation in a constant 50º left bank descent down to no less than 150 feet off the ground and then pull-up again with all four jets trailing smoke. Moseley was apparently working on a 'smoothness problem' that was aesthetic and not a safety concern. Moneymaker's aircraft sustained heavy damage to the right wing, but he managed to make a safe emergency landing at El Centro. The entire right wing replacement cost $188,255.00 according to an estimate prepared by *Blue Angel's* maintenance crew.

The Navy ruled that pilot error was the cause of the midair collision but since the pilot was not negligent, he would therefore, not be disciplined. At the time of the accident, Moneymaker had been commanding officer of the *Blue Angels* for more than a year while Moseley had joined the *Blue Angels* about four months before the crash and had only sixty-one flying hours with the team. The accident report also recommended more flexibility in the training procedures to allow more room for the pilots to 'clear' the manoeuvres.

Spectators watched in horror as the main section of the Mirage 2000 wreckage slammed into a small building on the airfield perimeter, 300 meters away from the horrified spectators. (Arun Sharma)

24 OCTOBER 1989: A-4 SKYHAWK (RNZAF, *KIWI RED* AEROBATIC TEAM, RAUMANI, NEW ZEALAND)

On 24 October 1989 as the team returned from their regular practice session held over the Raumai Ranges, disaster struck. Practicing their normal airshow finale, the 'roll-under-break', Red 4 struck Red 5. With severe damage to the aircraft now trailing the refuelling hose and a plume of smoke from the damaged centre-line air-to-air refuelling pod, Red 5 executed a successful emergency landing. Aware of the population below, he declined to dump fuel and elected to stay with the aircraft.

Recovery for Red 4 was however, not possible, resulting in the tragic death of Flying Officer Graham Carter. In true military professionalism, within two days of the accident, the remaining five members were back in the air as an RNZAF Court of Inquiry was convened. An immediate ban was placed on the continued practise or use of the 'roll-under-break' manoeuvre and not withstanding the findings of this military court, an announcement was made that the 1990 *Kiwi Red* display schedule would be continued.

8 OCTOBER 1989: AVIONS MARCEL DASSAULT MIRAGE 2000 (INDIAN AIR FORCE, NEW DELHI, INDIA)

As in previous years, the Indian Air Force celebrated the annual Air Force Day on 8 October 1989. To mark the occasion, a parade was held in the capital of New Delhi where VIPs and important dignitaries gathered at the Palam Air Force Base. This particular Air Force Day Parade was no different from the earlier parades except it ended on a tragic note. During the final event of the day, the solo aerobatics display, a Dassault Mirage 2000 of No.7 Squadron, flown by Wing Commander Ramesh Bakshi, the CO of the squadron, was killed in an ensuing crash.

Air Chief Marshal S. K. Mehra, Chief of Air Staff, inspected the parade. Important dignitaries such as the Chief of Army Staff, General V. N. Sharma and the Chief of Navy Staff, Admiral J. G. Nadkarni, were present on the occasion. Also gracing the venue were 2,000 invited guests who had come to watch the parade.

Wg Cdr Bakshi was one of the group of Indian Air Force pilots that were originally trained in France during the initial conversion conducted by Dassault Aviation. He had been with No. 7 as a senior Flight Commander for some years before taking over as the Commanding Officer and had more than 500 hours on the Mirage 2000. Towards the end of the display Wg Cdr Bakshi entered what was supposed to be the final manoeuvre of the day, an 'Upward Charlie' in which the Mirage would pull up into a vertical climb, rolling about the vertical axis of the climb before pulling into a high-speed fly-past in level flight.

After a short inverted flight, the Mirage 2000 suddenly pulled down into a vertical dive now repeating the same downline rolls. Wg Cdr Bakshi completed three rolls but somewhere along the rolling dive there was a slight hesitation in the Mirage's attitude before it entered a fourth roll. Some officers in the audience, obviously realising that the high rate of descent would not permit an additional roll plus recovery, rose up from their seats in surprise as the aircraft went into the fourth roll. One Senior Air Marshal was heard to shout: "What is he doing?" The pilot recovered the aircraft back to near level flight but was too low (<30 feet) to evade a streetlight pole, clipping its wing resulting in a fiery dark mushroom cloud towards the west end of the airfield about 1.5 km from the venue.

Spectators watched in horror as the Mirage 2000 slammed into a small building on the airfield perimeter approximately 500 metres away from the horrified spectators *500* metres away from the saluting dais and just 300 meters from nearest spectators gallery. The aircraft exploded into a huge fireball and debris fell on a number of air force coaches parked nearby, completely gutting them. Some debris also hit the static aircraft display and at least one Mi-8 was leaking fuel after debris pierced its tanks. There was obviously no time to eject from the aircraft and the pilot was killed instantaneously in the crash impact. The explosion along a row of huts outside the airfield and the debris, killed one member of the public immediately and another died later in the hospital due to burns. Besides the two hut dwellers who died in the crash, another twenty members of the public were injured, but no casualties occurred inside the airfield. (Arun Sharma)

03 SEPTEMBER 1989: CT-114 TUTOR (RCAF FORCE *SNOWBIRDS,* ONTARIO, CANADA)

Fifteen minutes into the team's twenty-four minute performance, two aircraft of the Canadian Forces *Snowbirds* aerobatic team crashed into Lake Ontario while displaying at the Canadian National Exhibition (CNE) airshow, killing one pilot and injuring the formation leader. Capt. Shane Antaya, 24, who was in his second year with the team, was killed. Antaya had more than 1,800 flying hours in the military and was a former flying instructor. His mother, his wife and brother and sister were in the CNE audience and witnessed the crash.

The *Snowbirds* leader, Maj. Dan Dampsey, 36, ejected from his burning Tutor and parachuted into the water being retrieved by the rescue services and treated in hospital for minor injuries. Both of the Canadian-made CT-114 Tutor aircraft crashed into the lake and were destroyed; all of the Snowbird's fifteen remaining shows for the season were cancelled. Over the years, there had previously been seven other crashes at the CNE airshow, six of them fatal.

Things began to go wrong when seven of the red, white and blue aircraft were performing a spectacular manoeuvre called the 'Upward-Downward Bomb Burst'. Four of the aircraft streaming white smoke, began an upward climb in formation toward three aircraft also in tight formation, diving down directly at them. The two formations were supposed to pass relatively close to each other. But, according to videotape evidence, two of the aircraft flying the downward section, collided with each other. The canopy of the aircraft flown by Antaya impacted against the trailing edge of the leader's aircraft, Antaya's aircraft continued in the dive and plummeted into the lake; there was no indication of pilot ejection. Dempsey's aircraft, however, recovered from the dive but then burst into flames. Dempsey did not eject until flames had almost completely engulfed the Tutor as it spun wildly out of control just above the lake's surface. The two aircraft hit the water a few thousand metres apart, both just missing several of the pleasure boats whose occupants traditionally got the best view of the show. The other wingman in the three-man section landed safely after the accident.

After the crash, organizers placed the show on 'standby' while all participants were requested to be prepared to perform once the decision had been taken to continue. The show continued after the crash "because it's an airshow tradition but would not have continued if any spectators had been injured", said the show's public relations director.

Defence Minister Bill McKnight said the decision on whether to discontinue the *Snowbirds* team "is not a decision that will be made immediately. It will be made in calmer times." McKnight said that the *Snowbirds* are "the cream of our youth and are important to keep as a show team because they demonstrate the high degree of training and capability of personnel in the Canadian Armed Forces".

17 JUNE 1989: HARVARD AT-6D (EARLE, ARIZONA, USA)

S. David Griggs, 49, an astronaut who had ridden on one Space Shuttle mission and was scheduled to pilot another in November 1989, died when the World War II vintage AT-6 aircraft he was flying, crashed in Arkansas. "Griggs was killed instantly in the crash near Earle; he was flying solo and performing rolls in the AT-6 when its wing clipped the ground and crashed in a wheat field near the company's hangars", said an Arkansas State Trooper. Griggs was flying for the McNeely Charter Service, a private air service based in Earle.

A Federal Aviation Administration investigator told the Associated Press that Griggs was practicing to perform at an airshow in Clarksville, Arkansas. "It occurred while he was off-duty, in a private aircraft and in his private capacity. Since it was not a NASA aircraft, NASA would probably have minimal involvement in the accident investigation.

9 JUNE 1989: MIKOYAN MIG-29 (PARIS AIRSHOW, FRANCE)

A MiG-29 crashed at the 1989 Paris Airshow when an engine failed during a vulnerable point in the display sequence. Although there was speculation that the pilot had skilfully pointed the aircraft at the infield after the failure, this claim was questionable. The MiG-29 was performing a 'high alpha pass', an extremely slow airspeed pass, when it reportedly ingested a bird which caused an engine to fail. However, Soviet officials later blamed a previously unencountered type of engine stall for the crash.

At that slow speed with one blower lit at that altitude, the inevitable occurred, an uncontrolled yaw/roll moment caused by asymmetric thrust effects rolled the aircraft into the dead engine and away from the spectators. The display pilot, Anatoly Kvochur, ejected extremely late but survived with hardly a scratch even though his parachute had barely opened. Fortunately, it had been raining heavily and the pilot survived the hard impact in soft ground.

In late 1990 there was a short interview with Anatoly Kvochur in the Hungarian bi-monthly magazine *Repules*. He said this about the accident: “I am a long-time MiG-29 pilot and I have experienced and solved this situation on several occasions previously. So I acted as usual, did nothing and waited for the engine to regain RPM spontaneously. This time it did not happen, this is why I'm convinced there must a foreign object suck-in involved in the stalling of engine. By the time I realized turbine will not give thrust, the plane's nose already draw a large arc towards the earth. I think I was a bit late in pulling the seat's handle.” An understatement or what?

28 AUGUST 1988: AM-339 (ITALIAN AIR FORCE *FRECCE TRICOLORI,* RAMSTEIN, GERMANY)

Three aircraft of the Italian Air Force precision aerobatic team *Frecci Tricolori* collided during an airshow at the USAF base in Ramstein, Germany. After colliding with two other aircraft, the solo aircraft crashed into the spectators' enclosure, killing approximately forty of the spectators during the first minutes and injuring several hundreds.

A fighter pilot at the airshow commented: “When I first went to the ‘show line' with my wife and son, I naturally went to airshow centre, in front of the tower. But it was way too crowded, so we moved off west approximately 2,000 ft; best move I ever made in my life; we had initially been very close to the impact point. I distinctly remember watching the solo MB-339 come across the valley towards us and thinking his a bit late, he was unloading to accelerate, HE'S GOING TO HIT – I turned away to grab my wife and kid”.

“The solo appeared to be late based on what seemed to be an acceleration manoeuvre as he approached the crowd, he unloaded to accelerate, instead of flying a smooth arc. This was REALLY obvious to all the aviators there. At the last moment, HE PULLED UP, right into the crossing planes! That's what I saw that made me know he was going to hit, before he did”.

The singleton collided with two other aircraft that crashed on the runway. The singleton's aircraft, flying directly at the spectator's enclosure, ploughed into crowds. (Reproduced by kind permission of Robert Stetter)

Why did he pull up? Why not go under the formation? Well, besides the fact that the standard procedure was to crossover the top of the approaching formations, it was also the standard procedure that had always been practiced and was ingrained in his mind. To make an in-flight decision to take an alternative option and squeeze in below the formation – well, there simply wasn't enough time to analyse the dynamics and make a decision to go against practiced routine. It could be argued that such decisions should have been considered during the development of the routine, but even then, unrushed decision making would have most probably have ruled this option out as an improbable case.

Another possible reason was that since Ramstein is on the side of a valley, and the terrain slopes up from the autobahn towards the runway, the tower/hangars and trees appear higher. A pilot coming across low towards the runway would not see any blue sky, but trees and buildings. So the visual illusion would be that there is no clearance unless you drop real low and fly up the contour of the terrain.

"I am convinced that as he came across the valley in a shallow unloaded accelerating dive (possibly higher than he was used to) and since being late, he cut off the bottom of his arc and hadn't 'bottomed out'. He was looking for clearance below the crossing formations and instead of seeing some blue sky, he saw nothing but buildings, trees, and the crowd. At that instant he decided he didn't have enough room to go under the rest of the team without hitting the ground and crowd and just pulled as hard as he could - right into the formation".

"The sad thing is that he had room underneath, at least 100 ft. He could have just eased down and flown up the contour, and the result from all present would have been a, WOW! Damn, I wish he had done that. I remember seeing the impact, thinking this is going to be ugly and turning to my wife and son and pushing them to the ground before the MB-339 even impacted".

The heat from the impact of the second MB-339 was felt by all the spectators within 500 metres of the aircraft. The impact point was near the Army 'medevac' Huey that was on standby adjacent to the runway and killed an Army aviator. A British 'medevac' Puma crew who had all their gear spread out around their helicopter in the static display park, threw all their gear back in and immediately took off, surrounded by stunned spectators and started doing their job within minutes of the crash. Watching all of Ramstein responding to the calls for blood donors, again within minutes, while at the same time there were Germans protesting against airshows outside the main gate – pure irony. Made their day, I guess".

"I had to hold my son and wife, as they were sobbing and pointed up to the remnants of the *Frecce's* formation as they rejoined overhead, with at least one of the MB-339s trailing smoke or fuel. They circled twice, then headed off to land at Sembach AB. I told my seven-year old son that despite what had happened, they had to rejoin and see who was OK, and if they could do that, we could also do it, and that seemed to calm him down a little".

A spectator caught up within the impact area commented: "It was truly scary as hell - hot ash and blast flew right over my head; I even had some lady knock me flat on my arse as the crowd freaked and 100,000+ people all stampeded out. If the aircraft that crashed into the crowd had not first hit a small shack on the side of the runway, things could have been much worse."
The (USAFE) accident investigation report stated that there was human error, a 'misjudgement', but refused to elaborate.

26 JUNE 1988: AIR FRANCE AIRBUS A320 (MULHOUSE-HABSHEIM, FRANCE)

The weather conditions on over Mulhouse-Habsheim were ideal for the demonstration flight of the newly delivered, Air France Airbus A320-100, registration F-GFKC. With 136 persons on-board, Air France had agreed to a request from the Mulhouse Flying Club for two fly-bys by a charter flight at the annual Mulhouse Flying Club airshow. As part of the airshow, the crew was tasked for two fly-by's, the first at low speed in the landing configuration at 100 ft and the next at high speed in the clean configuration. The automatic go-around protection ('Alpha Floor' function) was inhibited for the manoeuvre.

With Michel Asseline as the pilot-in-command, the aircraft had taken-off from Basle-Mulhouse at 2:41 p.m. local time and climbed to 1,000 feet agl. The crew commenced the descent three minutes later to 450 ft agl with Habsheim in sight. Pierre Mazière the first officer, informed the Captain that the aircraft was approaching 100 ft agl at 14:45:14. Eight seconds later, the descent had continued to 50 ft and thereafter, further to 30 ft agl without levelling-off. Go-around power was added at 14.45:35, twenty-one seconds after reaching the planned 100 ft agl. The A320, however, continued the descending trajectory and ploughed into the trees at the end of the runway at 14:45:40 in a 14° pitch attitude and an engine speed of 83% N1. The aircraft had slowly sunk into the forest while continuously descending.

A fire broke out on-board resulting in three fatalities and approximately fifty injured out of the 136 occupants on-board marking the first accident of a "Fly-by-Wire" aircraft at an airshow; the first of a few aircraft of this type that would be lost in the next few years during operational service. The aircraft was totally destroyed by the successive impacts and violent fire which followed. The official investigation concluded that the pilot had allowed the aircraft to descend through 100 ft at too slow an airspeed and at maximum angle of attack and was late in applying go-around power. A contributory factor listed unfamiliarity of the crew with the landing field and lack of planning for the flyby.

But there was a lot more to this airshow accident. The aircraft was fitted with the latest flight control system technology and a lack of confidence in the highly computerized aircraft would have meant a commercial disaster for Airbus, not only for the Manufacturer, but also for the French administration, which had a share in the European Airbus consortium and many conspiracy theories consequently originated.

Mr. Asseline, a former Air France pilot, was sentenced to ten months in jail by an Appeal's Court for manslaughter, but he always maintained that the flight data used by investigators and displayed at the trial, was a fabrication. The crew, and Air France maintenance officials, were also all sentenced to probation for manslaughter. There were reports of evidence, including photographs, subsequently showing an Airbus official at the scene allegedly switching the Digital Flight Data Recorder before the court hearing. It was also reported that the black box was replaced with another after the accident. Ten years later in May 1998, the Lausanne Institute of Police Forensic Evidence and Criminology (IPSC) concluded that the recorder presented to the Court was NOT the one taken from the aircraft after the accident.

The Captain's version of the accident was that he had flown the aircraft manually. He had been instructed by Air France to over-fly the airfield at 100 ft agl but when he increased throttle to level off at 100 ft, the engines did not respond. After a few seconds he became concerned and thought there was possibly a short-circuit in the completely computerized throttle control and therefore retarded the throttles all the way. He then opened them up again, but by that time, the aircraft had scraped the trees. After the accident, Captain Asseline was astonished when he saw on an amateur videotape that the undercarriage was only 30 ft agl when the aircraft was passing over the runway. He confirmed the altimeter of the Airbus A320 had indicated 100 ft.

Interestingly enough, no fewer than fifty-two provisional flight notices were subsequently published by Airbus Industry between April 1988 and April 1989. An Operational Engineering Bulletin (OEB) is a temporary notice sent out by the manufacturer to the users of an aircraft and forms a list of anomalies or simply functional features that do not appear in the Users' manual. Two OEBs were particularly interesting in relation to the Habsheim crash:

OEB 19/1 (May 1988): Engine Acceleration Deficiency at Low Altitude. Did this imply that it was already known before the accident that the engines sometimes did not respond normally to the pilot's commands on the Airbus A320? If so, did Air France inform their pilots about this anomaly? After the Habsheim accident, the engines were subsequently modified (OEB 19/2, August 1988).

OEB 06/2 (May 1988): Baro-Setting Cross Check. It stated that the current design for barometric altitude indication on the Airbus A320 did not comply with airworthiness requirements. Could this be an indication as to why the aircraft was as low as 30 ft (9 m) above the runway whereas Asseline confirmed that the altimeter indicated 100 ft (30 m)?

These OEBs were apparently sent to Air France but they had not been handed down to the pilots. In fact, both the engine and the altimetric systems were modified after the crash, which implies that they possibly did not function correctly at that time, but Airbus Industry was not held responsible by the French Court, the responsibility was placed on the pilots and the airshow organizers.

The only change in Air France operating procedures after the airshow crash was a firm policy that henceforth prohibited the carriage of passengers at airshow appearances. A later report by the French civil aviation authorities, casting aside the conspiracy theories, contains the first independent confirmation that the accident was caused by pilot error which the pilot's union, of course, contested. The report recommended an eight-year suspension of the pilot's licence and a two-month licence suspension for the co-pilot. Officials familiar with the flight recorder evidence say that despite the pilots' assertion that the aircraft was slow in responding to the controls, the flight control computers probably prevented a worse disaster by keeping the aircraft unstalled when the pilots realized too late that they were about to crash. Among several of the 'experts' in this field, the flight control system was not considered to be contributory, "there was nothing wrong with the flight control system - the pilot and operating authority just did not fully understand it, which of course does not make it right!" it was said.

24 APRIL 1988: MCDONNEL DOUGLAS F-18 (MCAS EL TORO, USA)

In the words of one of the expert witnesses, "the F-18 was scripted to pass the crowd at 350 kts and convert straight up into the vertical to demonstrate the climb capability of the aircraft. The aircraft came by at what appeared to be more like 250 knots, did a steep pull-up, and performed what looked like a 'square loop' to fly inverted. The problem was that the aircraft was less than 200 knots, and less than 1,500 agl when inverted. As soon as the pilot converted down, the crowd knew that he wasn't going to make it".

This was only speculation of course, but it is suspected that the pilot, a seasoned, senior officer, also knew he was in trouble. At the bottom, spectators watched 'full burner' come on as the pilot attempted to increase the aircraft's potential energy for conversion to radial 'g'. When the aircraft impacted, the pilot received massive injuries to his face and chest but the main injury was compression fractures of his vertebrae from the impact. Amazingly he survived but later retired on medical grounds. In the aircraft's extremely high nose-up attitude at impact, the cockpit was at least 15-20 feet above the ground when the tail hit. Imagine being slammed down to the ground in that situation and living to tell the tale.

The aircraft hit the ground hard, more or less flat but with the tail hitting first, the aircraft remained in one-piece, illustrating the incredible strength of today's composite airframes and not much fire either. For a few seconds after the crash, everyone was in a state of shock and not certain they could believe what had just happened. The aircraft was subsequently repaired and surprisingly, reintroduced into active Service. There was an episode of Rescue 911 that profiled this incident, the pilot's recovery in the hospital at home, and his return to the skies when 'Sandy' Sanders took him up in his red Lockheed T-33. (A detailed analysis of the causal factors of this specific accident is included in Chapter 5, The Demonstration Pilot).

16 APRIL 1988: AERMACCHI MB-326 IMPALA MK 1 (SAAF, *SILVER FALCONS* , STELLENBOSCH, SOUTH AFRICA)

The solo aerobatic pilot had just broken away from the formation to commence his solo display at the annual Stellenbosch Air Club airshow. Rolling inverted, he noticed an 'Engine Overheat' warning light illuminate, he immediately rolled wings level and the Fire Warning light then illuminated. When he tried to turn right to position the aircraft away from a nearby town, he discovered that he had no aileron or elevator control. An engine bay fire (external to jet pipe) had burnt through the aileron and elevator control rods that passed through the engine bay, rendering the aircraft uncontrollable.

The pilot ejected safely but not before some anxious moments as the burning aircraft made a 'dirty-pass' on him while he descended by parachute. The aircraft impacted against a cliff in the surrounding mountains without causing any collateral damage. Time from first warning to ejection was approximately twenty-five seconds.

The cause of the engine bay fire was attributed to the immediate past rectification of an unserviceability. The tail section of the aircraft had been removed and refitted to rectify another snag and when the diesel pipe for the smoke generator was refitted, the connector was not tightened properly. Diesel oil under pressure escaped and pooled on the fuselage skin adjacent to the jet pipe where it ignited. The procedure for fitting the connection did not specify a torque setting or locking of the connecting nut. Both procedural deficiencies were subsequently rectified.

10 MARCH 1988: AERMACCHI MB-326H (RAAF, *ROULETTE* S, AUSTRALIA)

The Canberra Bicentennial Airshow was scheduled for 13 March 1988 and the Royal Australian Air Force aerobatic team the *Roulette* s, were practising for the display and media call with a Channel 10 cameraman in *Roulette* 4. During one of the manoeuvres, *Roulette 4's* aircraft pitched-up and struck the underbelly of *Roulette* lead. *Roulette* 4 pilot, Flt Lt Crispin, ejected approximately 2 nm northeast of RAAF East Sale, Vic at 4,000 ft and 200 kts and sustained only minor injuries while the leader, Geoff Trappett, performed a successful wheels-up landing at RAAF East Sale.

15 DECEMBER 1985: AERMACCHI MB-326H (RAAF, *ROULETTES,* VICTORIA, AUSTRALIA)

The Royal Australian Air Force's *Roulette*s aerobatic team suffered their first ever accident when *Roulette* 2 and *Roulette* 3 collided at 2,000 feet over the training area of new East Sale. Flt Lt. Steve Carter (*Roulette* 2) was killed instantly whi ejected from his aircraft as it disintegrated. He was able to parachute into a tea tree swamp on the "Lakeview" property from where an Esso helicopter medevac'd Flt. Lt. Brooks to the Base Medical Flight but unfortunately during treatment, he suffered a cardiac arrest and later died in the Gippsland Base Hospital.

13 JULY 1985: A-4 SKYHAWK (USN *BLUE ANGELS,* NEW YORK, USA)

A *Blue Angels* pilot died after a mid-air collision during an airshow at Niagara Falls International Airport, N.Y. The two A-4 Skyhawk jet aircraft collided during a head-on 'opposition pass'. Navy Lieutenant Commander Mike Gershon, of Pensacola Florida was killed but the other, Lieutenant Andy Caputi, 30, ejected from his aircraft and landed safely on the grounds of the Niagara Falls AB. Another *Blue Angels* crash occurred on 12 February 1987 near El Centro after a routine training mission.

14 MAY 1985: NORTHROP F-20 TIGERSHARK (GOOSE BAY, CANADA)

Only five months after the previous F-20 accident at Suwon, Korea, Tigershark No. 2 crashed while at Goose Bay, Labrador, this time killing the newly appointed chief test pilot, David Barnes. Barnes was in preparation for performances at the upcoming Paris Airshow when during the final aerobatic manoeuvre of the five-minute flight, the aircraft deviated from the planned profile and entered a shallow wings-level descent. The descent continued until the aircraft struck the ground. Although the aircraft was not to blame for either crash, the Tigershark looked bad in the media and there was a lot of finger pointing between Northrop and the United States Air Force.

The late Frank Sanders, who was deeply involved in airshow safety and accident investigation for the Society of Experimental Test Pilots, had a theory that the combination of very high roll rates and high 'g' available in the F-20, could make a pilot particularly susceptible to disorientation and/or GLOC (g-induced loss of consciousness, not to be confused with an ordinary g-induced blackout).

The USN Test Pilot School apparently tried to reproduce the effect in a T-38 and although the T-38 had a respectable roll rate of over 270º/sec at 350 knots, it had very little 'g' available at that speed and the roll rate decreased quite quickly with increased speed due to Mach effects. "We could either roll fast and pull a little 'g', or roll more slowly and pull more 'g', but still nowhere near the F-20's structural limit of +9g", so the experiment was pretty much doomed to failure.

In the book "Set Phasers on Stun", the chapter titled "Tigershark!" there is a short account of this particular F-20A crash near Goose Bay Airport, Newfoundland, Canada. The cause of the crash was attributed to a combination of human error, fatigue and G-LOC. The Canadian Aviation Safety Board determined that the Northrop pilot became incapacitated during or following the final high-g pull-up manoeuvre and did not recover sufficiently to prevent the aircraft from striking the ground. (Aviation Week and Space Technology, March 30)

There were actually three F-20s that were produced. One crashed in Canada, one crashed in Korea (inverted stall at low altitude), and the third one is in the LA County Museum of Flight. A fourth aircraft was mostly complete but the third one never flew again after Northrop gave up on sales in late 1986. None of the four aircraft were actually prototypes, but were pre-production standard, the production tools were mostly complete when the programme was terminated.

10 OCTOBER 1984: NORTHROP F-20 TIGERSHARK (SUWON, KOREA)

Northrop chief test pilot Darrel Cornell was killed when his F-20 crashed while flying a demonstration for the Royal Korean Air Force (ROKAF) at Suwon in Korea. Suwon AB was the Korean host base for a USAF 'tenant' unit. Darrel Cornell was on a sales and demonstration tour with his deputy, Dave Barnes.

Before the entire senior ROK Air Force and the USAF personnel stationed there, the flight had progressed well and the pilot had just concluded the performance when he began the routine again. Cornell had put his F-20 into a climbing roll with flaps and landing gear extended. While inverted, the engine flamed out from fuel starvation, the aircraft stalled and then plunged to the ground. The pilot attempted to eject but was only approximately 12 feet off the ground and was ejected straight into the ground landing just feet behind the aircraft's impact site, a rice paddy. The local farmers were working only yards from the impact point.

The Recovery Team was first on site, after a delay caused by the ROK Security Police who wouldn't open an access gate. Some immediate concern about the Hydrozine in the EPU caused the Recovery Team and a HH-53 'Super Jolly' which appeared on scene to provide aid, to abandon the immediate area. Very little fire erupted but the hydraulics and oxygen, fuelled a rice-paddy fire. The pilot was pronounced dead at the scene.

The only communication with the pilot just before the fatal crash was apparently: "I'm glad its over, I'm tired" or something to that extent. The demo team had just completed a tour of the Pacific Rim countries trying to find buyers and the ROKAF was apparently ready to sign delivery contracts up until the crash. The two F-20's were being flown on 'demo hops' all day previous to the crash. The ROKAF wanted a replacement for the fleet of F-5E's but after the fatal crash, the sale of the privately funded fighter came to a halt. The F-20 may have had it's limitations but there are many pilots that still think Darrel Cornell gave one of the best demonstrations ever seen at Farnborough 1984 flying the F-20.

04 SEPTEMBER 1984: DE HAVILLAND CANADA DHC-5 BUFFALO (FARNBOROUGH AIRSHOW, UNITED KINGDOM)

The Buffalo had just completed a demonstration flight at the Farnborough Airshow when the pilot made a typical fighter approach to Runway 25. On short finals the Buffalo suddenly descended rapidly as the pilot turned tightly to avoid hammer-heading final approach to land. The excessive rate of descent caused an extremely heavy landing, the nose-wheel assembly and both wings catastrophically failed on touchdown due to excessive loading. Debris, including parts of the propeller blades caused damage to vehicles and other nearby aircraft. There were no fatalities but the two pilots and one passenger on-board, were injured.

The cause was attributed to human error with contributing factors of unfavourable weather conditions, a transitory handling problem whilst flying outside the tested flight regime and the pressure on the pilot-in-command to complete the flying sequence in an effort by show organisers to keep the show flowing. Ironically, flying supervision came under some blame for this for accident for 'over stressing' the importance of the requirement to maintain the display lines. Allegedly the comment made by the show supervisor to the pilots was: "the next guy who flies through the show line will be grounded". Was this pressure induced failure?

There have been a fair number of landing accidents by medium lift transport aircraft at airshows. At the 1985 Paris Airshow, a similar accident occurred. On completion of the display by a Dornier, the aircraft landed off a very steep approach that resulted in an extremely hard landing. The wing structure broke on impact and the aircraft ended its landing roll with part of a wing dragging behind the aircraft. Fortunately no one was injured but the aircraft was badly damaged.

Another, at RIAT 2002, RAF Fairford, the Italian Air Force pilot of a Alenia G-222 'overcooked' a battlefield assault approach. From a steep approach the pilot underestimated the 'flare-height' and put the nose-wheel assembly through the cockpit floor.

27 MAY 1983: TRANSALL C-160 (SAAF, AFB WATERKLOOF, SOUTH AFRICA)

A SAAF C-160 was practicing for an upcoming airshow at AFB Waterkloof, South Africa. The C-160, as a medium weight battlefield support aircraft, had an impressive short field performance capability as one of the main design features and was thus planned as the climax to the display sequence. The crew planned to fly two flypasts, a high speed run and then a low speed run with ramp and para-doors open and undercarriage down, culminating in a short landing.

Flown by a crew of three, the aircraft was set-up on final approach in the short-field landing configuration. The checklist was completed but due to pilot workload and cockpit resource management deficiencies, the aircraft touched down with undercarriage up and slid to an extremely short-landing. Fortunately, no significant damage to the aircraft or crew occurred, except for their egos of course. In this specific accident, the domino principle was best demonstrated. A crew was appointed to do the display but time and aircraft availability prevented them from practicing. When an aircraft eventually became available, only the two pilots from the assigned crew were available so other crewmembers were substituted for the practice flight and this 'patched crew' departed for the practice. No formal briefing was conducted and only a very rudimentary crew briefing was done.

Once airborne, they were pressed for time as it was near closing time for the base and they were rushed to complete the sortie. They elected not to lower the undercarriage for the flypasts and nobody in the cockpit checked for undercarriage on downwind before landing or on final approach for landing; the ATC gave landing clearance without the customary '5-greens' call from the pilot and ATC did not confirm the position of the undercarriage.

This was not the first time that a C-160 Transall had done a wheels-up landing at an airshow. This also happened at the Paris Airshow in 1981; two C-160D Transalls dropped parachutists and then conducted a two-ship display. The first aircraft landed followed by the other. The latter bearing German colours of MBB, attempted to execute a shorter landing with a tighter approach. In the rush, the undercarriage was extended but apparently not locked and the undercarriage then retracted on touchdown, the aircraft sliding along the runway on its belly. The aircraft suffered only minor damage and the crew, safe, then continued by having an argument on the edge of the runway. Strangely, this is not an unusual characteristic trait following a survivable accident – apportioning blame seems to be the first defensive mechanism of the pilot and verbal assaults and even 'punch-ups' have reportedly occurred. This was most certainly also the case in the collision between the two MiG-29s at RIAT in 1993.

11 SEPTEMBER 1982: CH-47 CHINOOK (US ARMY, MANNHEIM, WEST GERMANY)

Forty-six people were killed when a U.S. Army Chinook helicopter carrying skydivers from several nations crashed at an airshow at Mannheim, West Germany. Without question, the loss of this aircraft resulted in the worst and most tragic airshow accident in the history of airshows at that time, it was also a huge blow for the Chinook and all helicopters in general.

The City of Mannheim had requested two Chinooks to drop skydivers at the airshow for the 375th anniversary of the city. Although both helicopters arrived on schedule, instead of two Chinooks executing the mission, a decision was made to take only one aircraft. The skydivers wanted to set a world record by forming the largest joined circle of free-falling skydivers ever accomplished. As a result, forty-six people climbed aboard the single Chinook but since there were only thirty-three seats available in the cabin, eleven parachutists remained standing.

The aircrew planned the drop at 13,000 feet and after climbing for about twelve minutes to an estimated altitude of approximately 8,000 feet, the tower received a message from the aircraft that a problem had developed and it was descending and returning to land. At about the same time, the pilot of the second aircraft, watching from the ground, saw the 'chopper' start descending rapidly. Out of curiosity he jumped into the cockpit of his aircraft and on the squadron's 'natter' frequency, made contact. The pilot reported a flickering caution light, a mechanical noise and that they were returning to land. After a few minutes of autorotation, the pilot set up the helicopter to land on the airfield.

On passing approximately 600 ft, at the last moment, the aircrew decided there were too many people in the area where they were trying to land and the descent was halted in an attempt to cross the autobahn and land on the other side. When power was applied to arrest the descent, the in-flight break-up of the helicopter began. Witnesses on the ground reported hearing a loud bang and describing a “whooshing” sound. The aft rotor blades were seen departing the airframe and shortly afterwards, the aft rotor hub, along with half of the aft pylon, separated from the fuselage. A split second after half of the aft pylon separated, the aft transmission and the remaining portion of the aft pylon began to tear away from the airframe. The aircraft slowly rolled onto its right side as it continued to descend.

The helicopter crashed onto the autobahn between Mannheim and Heidelberg, bursting into a huge fireball on impact and creating a glowing mushroom cloud above the impact site. The ‘g’ force at impact was estimated at 200g which means that an average 180-pound person aboard the helicopter would have been subjected to a force of 36,000 pounds; there can be no doubt that death was instantaneous.

The failure of the Forward Transmission Input Pinion Capsule caused the Number 1 Synchronized Drive Shaft to rotate eccentric and contact the Forward Pylon structure, causing the shaft to fail followed by the subsequent de-synchronization of the Forward and Aft Rotor Systems. The forward and aft rotor blades meshed causing the aft pylon, aft transmission and the aft rotor system to separate from the helicopter with catastrophic results. The entire crew and all passengers received fatal injuries. The failure of the Input Pinion Capsule was caused by Walnut Grit, used to clean the transmission during the overhaul process, blocking the oil journals inside the transmission.

For many years prior to this accident, walnut grit was successfully used as an effective cleaning agent for the transmissions during the overhaul process. It is softer than the base metal, but harder than the contaminants that accrue inside the transmission. Shortly before this accident, a procedural change in the process was made by inspectors working for the Occupational Safety and Health Administration who examined the working conditions at Corpus Christi Army Depot. It was noted that high-pressure air at approximately 3,000 PSI, was used to blow the walnut grit out of the oil journals. This high air pressure was deemed hazardous to workers and it was ordered that the pressure be lowered. As a result, the walnut grit was no longer completely removed during the cleaning procedure and eventually, when the transmission was placed into service, the walnut grit would flow through the oil passages and accumulate in a point blocking a journal. A bearing would fail from the lack of lubrication.

18 JANUARY 1982: T-38 TALON (USAF *THUNDERBIRDS*, NEVADA, USA)

The *Thunderbirds* lost the entire formation team, all four, when Lead’s stick apparently jammed as he came down out of a loop and couldn’t pull out of the recovery dive during a training sortie. The formation of T-38s were seen to impact the desert at Indian Springs AFB, Nevada. in a line-abreast loop. Planned entry and exit heights for the loop were 100 ft.

The leader was Major Norman Lowrey, aged 37, who had taken over as team leader in October ‘81. No. 2 was Capt Willie Mays, 32 and No. 3, Capt Joseph Peterson, 32, both who had been on the team for two years. The newest member of the team was No. 4 was Capt Mark Melancon, 31, who had joined the team in October as ‘slot man’. The *Thunderbirds* had been under pressure following two fatal crashes in the previous season (9 May 1981 at Hill AFB, in which one of the team crashed inverted just outside the airfield.)

They went in, all in line abreast and impacted within 0.4 seconds of each other; the aircraft were slightly nose up when they hit. Nothing wrong with any aircraft. The first accident report concluded ‘pilot error’ but the USAF command told the accident investigation team to try again and they then came back with the actuator theory which was published in *Flight International*, 30 January 1982. The report that came out of the crash investigation found that an actuator rod on one of the control services had bent when the pilot pulled the stick harder coming out of a loop. He felt that he was giving it more input, but all it was doing was bending.

The original report being bounced back from HQ to the Board of Inquiry, from political masters to a board of specialists, generally does not bode well for aviation and airshow safety. The overriding of specialist findings by management in any organisation always tends to alert the inquisitive to dig a bit deeper, not necessarily understanding the strategic vision of such strong-handed political decisions. In fact, the second report raised more questions than answers and certainly raised suspicions of a cover up by the USAF. The rejection of the accident investigation report is dealt with in Chapter 5)

10 OCTOBER 1981: PITTS SPECIAL (AFRICA AEROSPACE, LANSERIA, SOUTH AFRICA)

In front of a crowd of several thousand spectators at the Africa Aerospace Airshow in 1981, the commentator counted out over the public address system as each turn of the inverted spin was completed. The aim was to conduct thirteen turns of the inverted spin and then to recover. South African aerobatic champion Nick Turvey recovered from the spin, but with inadequate height to effect a safe recovery pullout, the aircraft impacted approximately fifty metres behind the spectator showline in an open gully between the showline and the hangars. Miraculously the aircraft did not explode on impact and no one was killed but Nick Turvey was hospitalised for several months as his badly injured body recovered.

Miraculously the Pitts did not explode on impact and the no one was killed but Nick Turvey was hospitalised for several months as his badly injured body recovered. (P. du Bois)

This accident was marred by poor crowd control, the crowds surging forward to the crashed aircraft and hampering the rescue vehicles. It was obviously never envisaged that an aircraft would crash behind the crowd line. According to a witness at the time: "The show organisers clearly had no proper emergency plan in place, or they certainly didn't rehearse for it! From my own experience, I know how soon one forgets the drill when not practiced. No proper crowd control, no procedure (fire engine caught in the fence), too many people 'lending a helping hand' thus preventing the medic's from doing their job and no crew manning the emergency helicopter."

8 OCTOBER 1977: BRITTEN-NORMAN TRISLANDER (AFRICA AEROSPACE, LANSERIA, SOUTH AFRICA)

Britten-Norman Aviation, the UK based aircraft company dispatched their latest 1976 short-hop transport design, the Trislander, to Africa on a series of demonstration flights with the primary aim of achieving sales orders. The visit coincided with the annual 1977 Africa Aerospace show held at Lanseria Airport in South Africa.

Company test pilot Peter Phillips demonstrated the Trislander. The airfield elevation at Lanseria (near Johannesburg) is approximately 5,000 ft and with a prevailing temperature on the day of the accident at 30ºC the density altitude was approximately 8,500 ft. Amongst other manoeuvres, a loop was included in the demonstration sequence. During the practice sessions, it was evident to the pilot that the density altitude was critical to aircraft performance and the safe accomplishment of the manoeuvre. As it turned out, the sequence progressively lost energy with the result that at the apex of the loop, the aircraft was too low resulting in insufficient height to safely effect the recovery pull-out; it was estimated by reliable sources that the proverbial 'another 50 ft' might have been sufficient to avoid impact with the ground.

The aircraft impacted directly in front of show centre, bounced back into the air, the engines broke off and continued on their independent trajectories leaving the fuselage behind with the pilot and passenger inside. Fortunately there was no post-crash fire and the pilot survived the impact but the high vertical velocity at impact resulted in back injuries.

03 JUNE 1977: FAIRCHILD A-10 (PARIS AIRSHOW, LE BOURGET, FRANCE)

The classic story of the 'loop that kills you' - bad weather, too low, too close - the result, a hole in the ground. Despite a very low ceiling, the airshow programme continued at the Paris Airshow and the A-10, renowned as an agile close-air-support "tank killer" with the ability to manoeuvre in confined air space, was on show. It was 3.30 p.m. when the Fairchild A-10 entered the first vertical manoeuvre, a loop.

The highly experienced test pilot, Howard W. Nelson, one of the A-10 programme test pilots, pulled up into a loop; the aircraft entered the low overcast and the pilot exited the cloud completing the loop safely. The pilot pulled up for the next loop, attempting to fly the loop tighter this time to keep it from entering the overcast. The aircraft remained below the cloud ceiling and the recovery pull-out was commenced, but this time, the aircraft was too low and it impacted the ground, tail first before smashing into the ground. The aircraft immediately broke-up on impact, the tail and cockpit separating from the fuselage and the fuselage catching fire.

Comment by a spectator at the crash: “I estimate that another 50 to 100 feet was still required to successfully complete the manoeuvre. The pilot, I believe, barely survived the initial impact but regrettably died from the injuries sustained associated with the ensuing break up. I remember thinking at the time, geez - if he pull’s this manoeuvre off with what looked like a possible clearance of 10 to 20 feet above the runway, ‘struth - what a performance! Tragically it did not turn out that way though. It’s sad when any pilot dies”.

30 APRIL 1975: JAGUAR T.2 (RAF LOSSIEMOUTH, SCOTLAND, UK)

During an inverted pass overhead the runway at RAF Lossiemouth as part of a display practice for an upcoming airshow, a control restriction was caused by an unrestrained personal survival pack (PSP) in the rear seat. Instead of using the correct restraint cover to safety the ejection seat PSP and seat straps, the straps were tied-up with twine which allowed the PSP to dislodge and fall out while inverted and jam the control column. The pilot managed to keep limited control of the aircraft to achieve an ejection attitude and to command ejection before the aircraft crashed into the overrun. The pilot was suffered only minor injuries and there was no significant collateral damage.

01 SEPTEMBER 1974: SIKORSKY S-67 (FARNBOROUGH AIRSHOW 1974)

With the rapid advances in helicopter design technologies, it was not long before helicopters attempted to emulate the fixed wing manoeuvres and it was at Farnborough 1974 where the S-67 Blackhawk prototype crashed. The helicopter started the sequence of consecutive rolls too low and hit the ground on exit from the last of the two rolls. As one of the major commercial airshows, the S-67 was on-demonstration as Sikorsky was attempting to sell it to the Israeli Air Force.

Due to the constraints of early helicopter design, helicopters were prohibited from pulling negative ‘g’ otherwise the blades could easily strike the tailboom with catastrophic results - rolling and looping manoeuvres could therefore not be attempted unless they could be flown under positive ‘g’ throughout the manoeuvre. To do a straight roll in a helicopter thus requires a high nose-up pitch attitude prior to commencing the roll and a single roll only is usually flown – not consecutive rolls. However, should the pilot elect to fly two consecutive rolls, the nose-up pitch attitude would have to be so much higher because it was not possible to push forward to keep the nose on the horizon. In this specific case, two consecutive straight rolls were attempted but the helicopter crashed onto the airfield during the final part of the second roll. Fortunately the aircrew were only injured with no collateral damage being caused to infrastructure. A concise summary of the findings by the Board of Inquiry: *“The Commander made an error of judgement when initiating a roll manoeuvre at too low a height, although that height was sufficient had the manoeuvre been flown in the normal manner, and at a height which met the UK MoD, SBAC, Sikorsky minima.”*

6 MARCH 1973: TUPOLEV TU-144 (AEROFLOT, PARIS AIRSHOW, FRANCE)

On 6 March 1973 at Goussainville, France, an Aeroflot Tupolev Tu-144 crashed while performing during the Paris Airshow. The official synopsis of the accident was that after a very steep climb, the aircraft was observed levelling off very abruptly and then begin a dive. In the ensuing dive recovery, the aircraft broke apart in-flight and exploded, the wreckage hit the village of Goussainville and in addition to the six crew on the Tu-144, eight members of the public were killed and sixty injured, many of them suffering from burns.

Conspiracy theorists even speculated that the pilot, possibly startled by a close encounter with a Mirage jet photographing the TU-144, overreacted by pushing-over to a negative angle of attack causing a compressor stall. The aircraft then went into a dive and broke apart after the aircraft's design load-limit was exceeded.

However, an eyewitness account from an eminently qualified witness, world renowned test and display pilot, Bob Hoover, in his autobiography, "Forever Flying" he recorded: "The last day of the 1973 Paris Airshow was called the Public Day. More than one million people were on hand to view the air displays. On the Saturday night before Public Day, the French held a reception for all of the pilots flying in the show. Throughout the first ten days, there had been a fierce competition between the French Concorde and the Russian Tu-144, both supersonic transports. I believed the Russian pilot was exceeding his flying capabilities. On one landing, he overshot the runway and had to execute a go-around. On another, he landed short. At the reception, he boasted that on Sunday he would 'out fly' the Concorde. That day, the Concorde went first and after the pilot had performed a high-speed flyby, he pulled the Concorde up steeply and climbed to approximately ten thousand feet before levelling off".

"When the Tu-144 pilot attempted the same manoeuvre, he pulled the nose up so steeply that I didn't believe he could possibly recover without a whip-stall. I was observing the flight from the deck of the Bendix chalet with members of the Press. I yelled, "Get your cameras. He isn't going to recover." When the aircraft stalled, the nose of the plane pitched over violently into a steep dive and as he attempted to pull out of the dive, the airplane started breaking up, and pieces of burning debris rained down on a French village nearby."

Howard Moon's Book "Soviet SST: The Technopolitics of the Tupolev-144" discusses this accident at some length and entertains interesting conspiracy theory. According to Moon: "The fatal flight followed a spectacular ten-minute demonstration by the Concorde, which the Tu-144 crew witnessed as passive sp while waiting for takeoff. According to some reports, the Tu-144 crew was under pressure from Moscow to stage a spectacular flying display. The ensuing exhibition featured the 144 swaying from side to side and with steep banks and turns at very low altitude. Mikhail Kozlov, the pilot, had told colleagues two days before, "We have a few tricks. We have more power than the Concorde".

When the aircraft stalled, the nose of the plane pitched over violently into a steep dive and as he attempted to pull out of the dive, the airplane started breaking up, and pieces of burning debris rained down on a French village nearby.

Moon concludes that the root cause of the accident was actually the rivalry between the Concorde and the Tu-144. A contributory cause is that the French cut back on the carefully rehearsed Soviet display flight time at the last minute and extended the demonstration flight time of the Concorde. At one stage of the display, the crew on the 144 were forced to improvise a landing and apparently tried to land on the wrong runway. As they went around for another landing, they were not in touch with air traffic control and found themselves on a collision course with a French Mirage III.

To complicate matters, an alternative conspiracy theory proposed that the co-pilot had apparently been given a TV camera to shoot film for a French TV station during the flight. The negative 'g' avoidance manoeuvre caused the camera to fall into the control-stick-well on the cockpit floor. By the time it was removed, the only option was a violent recovery attempt, which led to the failure of the starboard wing. According to Moon, a Soviet simulator ran this scenario, and it duplicated the events at Paris. Despite this and other theories about technical problems, disintegration of the canards, stalled afterburners and fatigue cracks in the wings, Moon is convinced that 'technical factors' were peripheral to the fate of 77102. The precipitating factor in the disaster was political.

The TV camera that supposedly fouled the controls symbolizes the dangerous intrusion of publicity, but Moon contends that the one event that made the crash unavoidable, was the decision to cut short 77102's demonstration flight, practiced at least six times in the USSR. This would have left a disoriented pilot and crew above a strange airfield in an aircraft with notoriously poor cockpit visibility and it is thus understandable that Kozlov attempted to land on the wrong runway, or so it was claimed. Still pursuing the conspiracy theory, what seemed less excusable according to Moon, was that a second aircraft in the area forced a series of violent evasion manoeuvres, which even the robust '144 airframe could not withstand. Their boorish pressuring in the joint commission notwithstanding, it is hard to establish much Soviet responsibility for the crash. Moon concluded that errors may have been made in the demanding flying conditions over a crowded airshow, but the sloppy air control of the airport, the straying fighter, and the truncation of the '144 flight routine were the precipitating, critical events. The managers of the airshow appeared to be chiefly responsible for the disaster.

Moon doesn't discuss the Mirage and why it was where it was - it could have been an airshow participant or a platform for photographing the Tu-144, as suggested by conspiracists but photographs of the Tu-144 on the ramp show the canard surfaces deployed for all to see. Given this, plus the surfaces being used during the flying displays in front of the crowd, just what advantage would photos from the Mirage have given? So, was the Mirage really there to shoot photos or was it just there for some other, maybe totally innocent, reason? If it was there at all! To date there has never been any firm evidence corroborating the alleged Mirage III 'plot', although the story seems to have been repeated for so long now that it has become the 'truth'.

There's also the issue of compressor stall, which Moon doesn't really discuss either in his analysis. According to Moon, one of the major problems encountered with the Tu-144 was inlet design. It was one of the major design problems with the Concorde too, - half of its wind-tunnel time was devoted to solving this problem. In 1977, the USSR approached the Concorde consortium for help with inlet design and control systems but was turned down because of the military applications of the technology.

Another viewpoint expressed by an experienced pilot at the show: "After these passes, described as 'spectacular' and 'over-done,' the 144 indulged in a low-speed exhibition of the superior low-speed handling provided by the canards. This was described as a low-speed 'worm-burner' skim over the grass at minimum altitude. Immediately following this low-speed pass, and with canards and landing gear still extended in low-speed trim, Kozlov pitched the 144 into a steep climb with all afterburners lit. The 144 climbed to about 3,000 feet and then experienced what appeared to be a full classic stall, wobbling about all three axes, yawing to the left and then diving steeply. Some witnesses said that two pieces separated from the aircraft at this point, possibly the canards, which led some to conclude that the canards' debris had pierced the wings or possibly entered the engines. But most believe that the canards were still out and did not break off. The steep dive that followed indicated that the 144 was in mortal peril for there was only 3,000 feet to recover, and the 144 was a large and heavy aircraft."

"Kozlov came close to levelling out the 144 after an almost-vertical drop of several seconds, but the recovery was too abrupt, with the right wing breaking off at the root and the subsequent roll breaking off the other wing. Two engines were quickly engulfed in flames and several explosions rocked the stricken aircraft as it tumbled to earth in incandescent lumps of titanium and steel. Many expert witnesses agreed that the 144 had been taken beyond the limits of its flight envelope. It had no 'g-levelling' device that prevented it from being manoeuvred beyond the strength of its airframe. The explosive disintegration was the result of a desperate, foredoomed attempt at recovery".

In another viewpoint expressed by James E. Oberg in his book "Uncovering Soviet disasters; exploring the limits of Glasnost" ISBN 0394560957, he wrote: "On June 3, the last day of the air show, the two different Mach 2 airliners flew head to head before a crowd of 200,000 aviation fans. First the Anglo-French Concorde made a magnificent flyby and circuit of the field, performing more like a fighter jet than a passenger airliner. The crowd was impressed. Then it was the Tu-144's turn. Pilot Mikhail Kozlov did his best to outperform the Concorde, completing a series of manoeuvres with a low flyby along Runway 060. As he came along the runway in front of the main reviewing stand, many aviation experts and journalists grew apprehensive over the airplane's low airspeed. They saw the plane's afterburners kick in, painting shock diamonds behind the four engines. As the plane reached the end of the runway, it pulled up into a climb which rapidly became dangerously steep. "Shoot him, shoot him!" one bureau chief cried to his cameraman. "He's not going to make it!" Kozlov's nearly vertical climb had had its intended effect: The crowd 'oohed' in amazement. The admiration then suddenly turned to horror. As clearly shown later in photographs, the left canard broke clean off from the stresses, which went far beyond the design limits of a commercial airliner. It smashed into the wing root behind it, and a small orange flare blossomed as the ruptured fuel tank exploded. The plane noised over and dived straight into the ground "like an arrowhead," one horrified newsman recalled years later."

With regards to the inquest, it seems reasonable that the French would not want their role in the accident made public. The presence of the Mirage, either deliberate or accidental, would not have looked good. This would hold true if it were there to take photographs or simply there as the result of an air traffic control error. Other actions by the airshow organizers that contributed to the crash would also not have reflected well upon the French. The Soviet desire for silence could have been a cover-up of technical problems with the Tu-144, or just a knee-jerk security reaction - the Cold War certainly saw enough of those.

It is interesting to note the two widely differing perceptions, the one by a display specialist Bob Hoover and the other by Moon. Whatever the theories, there are several basic display lessons to be learnt by display pilots, airshow organisers and Flying Control Committees.

04 JUNE 1972: F-4 PHANTOM (UNITED STATES AIR FORCE *THUNDERBIRDS,* DULLES, USA)

Way back in 1972 at Dulles International Airport's Transportation Exposition Airshow (Transpo '72), there was a huge exhibition on what future transportation might look like. They also had several airshow performers including the *Thunderbirds* - it happened there - the airshow organisers "nightmare scenario", there were three deaths over the duration of the exhibition. By the week's end, the organisers who promoted the show must have felt like calling it quits.

The first was when the 'pilot' of a hang glider on a towrope stalled and dumped it into the ground. The second occurred during a sprint race around pylons - the aircraft involved were fairly small and fast and while in a turn, the propeller of an outside aircraft hit the tip of the wing of the aircraft inside. The wing pretty much came off instantly and at less than 300 ft agl, the aircraft rolled fast and hit the ground so quickly that the pilot was still exhaling his first expletive when he died. The third was during one of the Thunderbird's more spectacular moves.

At that time, the *Thunderbirds* were flying the F-4 and on the last day of the show, Howard, the right wingman, was killed following a stab actuator failure (non-time change item). The team had just completed a five-ship wedge roll, and were in the first 40º of a 4-G vertical (90º) 'wifferdill' turnaround manoeuvre. Howard's flight controls were disabled and his aircraft left the formation uncontrollably at very high G, estimated by McDonnell Douglas to have been 17-25 positive G's which resulted in an immediate inverted stall, and a completely unflyable aircraft. Although Howard did manage to bail out at extremely low height, his parachute was ignited by the aircraft's fireball and he was killed.

He was an outstanding pilot and an inspirational and caring person. It was a tremendous loss to the team and of course, his family. The impact of such occurrences on the spectators is distressful, especially the wives and kids watching the accident. A comment by a spectator was that: "I don't think such accidents should cause airshows to be shut down. I do however, think that airshows increase the probability that people will witness tragic accidents as they happen. And these days it's not uncommon to see video footage on the evening news".

20 JANUARY 1971: FOLLAND GNAT (RAF, *RED ARROWS,* KEMBLE, UK)

Four pilots were killed in a mid-air collision near Kemble when the two Gnats of the *Red Arrows* 'synchro-pair' approached each other head-on from opposite ends of the runway. Both aircraft were flying the horizontal carousel (roulette) manoeuvre (a flat, opposition 360º turn) and for this accident to happen, both had to have been on the same side of the runway at the crossover. In the subsequent investigation, members of the House of Commons questioned the continuance of the team but fortunately, Lord Carrington, the Secretary of State for Defence ruled that a seven-man team would continue but the carousel manoeuvre was subsequently classified as a prohibited manoeuvre for the next twenty-five years.

In preparation for a BBC Television filming, the aircraft were being flown by the current Synchro Lead and Synchro 2 who were giving dual instruction to their successors; it could never be conclusively concluded which of the four pilots were flying at the time of the accident. To ensure continuity within the Synchro-team, the Synchro-Lead is always a third and final year *Red Arrows* pilot, with Synchro-2, a second year *Red Arrows* pilot. The rule of thumb for conducting such head-on passes is that the Synchro-Lead flies the profile and Synchro-2 has the job of 'missing' Synchro-Leader.

4 JUNE 1967: FOUGA MAGISTER (FRENCH AIR FORCE, *PATROUILLE DE FRANCE,* PARIS AIRSHOW, FRANCE)

During the final event of the day, *Patrouille de France* flying the Fouga Magister, were assigned the closing slot for the day's proceedings. Finishing with the traditional final nine-ship bomb-burst, one of the aircraft did not manage to recover from the ensuing recovery pull-out and crashed near the official enclosure. Much of the crash debris was projected towards the crowd, including part of the engine which finally came to rest against the barriers separating the public from the runway. In spite of the chaos and panic that followed, miraculously nobody else in the crowd was injured and only Captain Didier Duthois, the deputy leader of the *Patrouille de France*, was killed.

19 JUNE 1965: FIAT G-91 (ITALIAN AIR FORCE, PARIS AIRSHOW, FRANCE)

The 1965 Paris Airshow will be remembered for the two fatal accidents that occurred. The second accident of the 1965 Paris Airshow occurred with the daily flying display programme approaching the end. The Italian Air Force Fiat G-91 had completed its demonstration and approached Runway 03 for landing. The G-91 got behind the power curve in a missed approach due to a Canadair Tudor being taxied onto the runway. The G-91 crashed into the parking lot about 300 metres from the threshold of the runway killing the pilot, Italo Tonati, (who did not eject) and nine spectators while destroying about sixty cars in the car park.

The first accident occurred on Tuesday 15 June 1965 and as in 1961, it was once again a B-58 Hustler. The aircraft was heavily loaded on arrival from Madrid, approaching for landing on runway 25, the aircraft literally lost an engine on finals and crashed just beside a taxiway almost in front of a Husky Fire-fighting helicopter waiting to cross the active. The Huskey just flapped over and dumped the load on the cockpit and immediately extinguished the fire. The pilot was killed in the accident while the two other injured aircrew members were evacuated to Paris by helicopter. The airshow organisers had another aircraft there for the final Sunday and the crash rescue crews were suited up all along the runway inside their trucks all the time it was in the air.

16 JUNE 1963: HAWKER SIDDELEY P.1127 (PROTOTYPE HARRIER, PARIS AIRSHOW, FRANCE)

Sunday, the last day of the flight demonstrations of Hawker Siddeley's experimental P.1127 vertical take-off and landing jet. Demonstrating hovering flight after having presented rearward flight, the aircraft transitioned to forward flight. At this time the P.1127, still within ground effect, ingested foreign objects which caused perturbations to the airflow and consequently, engine operation. According to one of the French witnesses, "the FOD partially choked the nozzles and then the exhaust outlets which, without being commanded, rotated from the vertical to the horizontal, resulting in the aircraft falling heavily to the ground. The fire-rescue services immediately intervened and sprayed foam over the aircraft. Fortunately the aircraft did not catch fire since the fall was only a few metres. The pilot, Hawker's world renowned test pilot A.W. 'Bill' Bedford escaped from the accident without injury. The aircraft was repaired and was thereafter able to resume its role in the experimental flight test programme, eventually giving birth to the Harrier.

3 JUNE 1961: B58-A HUSTLER: (USAF, PARIS AIRSHOW, FRANCE)

On a late Saturday afternoon and against a low cloud ceiling, the B-58 performed a barrel roll, entered the overcast and re-appeared in a steep nose-down attitude with insufficient altitude to affect the recovery pull-out, crashing into an uninhabited area near Louvres. All three crewmembers, the pilot Elmer E. Murphy, the navigator Eugene Moses and the radar operator David Dickenson, were killed. Spatial awareness and disorientation led to there being inadequate time or height available to effect an ejection.

6 SEPTEMBER 1952: DE HAVILLAND DH110 (FARNBOROUGH AIRSHOW, UK)

John Derry's fatal accident at Farnborough in the de Havilland DH-110 followed the first pass in which the crowd heard two distinct booms. On the next pass, when Derry arrived over the field, the aircraft disintegrated during an entry into what could best be described as a climbing roll - the wingtips failed, causing a violent pitch-up that overstressed the airframe and the tail-booms broke away, the aircraft plunging into the spectators.

According to a witness who was standing directly in the path of Derry's engines, the engines crashed down into the crowd and just missed him! His friend, standing right beside him, was spattered with blood from nearby victims of this tragic accident. The accident killed pilot John Derry, his navigator/observer Tony Richards and twenty-eight spectators during a high speed pass. Interestingly, the show continued immediately afterwards with Neville Duke doing a maximum speed flyby, transonic, in a red Hawker Hunter.

The DH110 was a transonic fighter-bomber designed in the early 1950's. During final assembly of the prototype it was found that its wing tips would not fit properly and so they were literally bent into place! Six months after the crash, it was discovered during the structural test programme that the wings were not strong enough, they had been designed to withstand loads in bending and not in torsion. Quality, in its broadest sense seemed to be absent.

2003 AIRSHOW ACCIDENTS

The year 2003 marked a special year in the exhibition of aviation's impressive feats, the 100th anniversary of manned flight. All over the world, themes at airshows commemorated man's achievements. However, the 2003 airshow year was off to a typical start with at least seven accidents in the first five months. As early as 3 February 2003, a Su-29 AR of the Argentinean *Cruz del Sur* Aerobatic Team crashed during display practice, resulting in the death of two pilots. The accident happened about 25km from Mendoza and the two pilots who died were Vice Comodoro Cortez and Captain Danilo Soldera.

In a major blow to the European airshow circuit, the French Mirage F1 duo, *Voltige Victor* crashed on 10 March 2003 while the team were practicing at their home base of Reims. Reports stated that they were flying in close line-astern at low-level (300 metres) rehearsing their display routine for the 2003 airshow season when the number two aircraft pulled up slightly and hit the Leader's tailplane. One of the aircraft crashed at the end of the runway while the other came down in a field about 500 metres away. The two pilots who were killed were Team Leader Lt. Guillaume Coeffin, 32 years old, on his second year with the team, and the No. 2 pilot, Lt. Michel Vernat, also 32 years old, on his first year with the team.

On 22 March 2003, a late Saturday airshow crash at Tyndall AFB claimed the life of a talented civilian pilot flying a Technoavia SP-95 aerobatic aircraft. Chris Smisson, a highly accomplished member of the *Airshow Unlimited Airshow Team*, flying at the Gulf Coast Salute 2003 Airshow at Tyndall Air Force Base, was killed in a 'near vertical' impact that reportedly occurred as part of a 'faux race' between his aircraft and a jet-powered truck. No personnel or spectators on the ground were injured. One spectator described the impact as a "head first" impact with the ground as the aircraft was coming out of a loop (supposedly in preparation for a high-speed low pass) as part of the aforementioned race, when the accident occurred. Another witness stated, "He didn't pull up or anything. He just crashed."

The Technoavia SP-95 is a Russian built, M14-P radial powered two-seater produced for high performance aerobatics. There were only a few in the country and two were listed on the roster of the *Airshow Unlimited Aerobatic Team*. According to his extensive bio, Chris Smisson had over 14,000 hours of flying time and flew professionally for a major airline out of Atlanta, GA. Chris was the United States Intermediate Glider Aerobatic Champion in 1989 and was a member of the United States Glider Aerobatic Team in 1991. Chris had been doing airshows since 1986 and held a Surface Level 1 waiver with qualifications in the North American T-6, Beechcraft T-34, the Zlin 526F, Technoavia SP-95 and Pilatus Aircraft as well as Gliders. He also held waivers for Solo Aerobatics as well as dogfight demonstrations – he was a highly qualified display pilot.

On 17 April 2003, during the aircraft's third aerobatic training sortie from its base Linz/Hoersching, prior to a display in France, an Austrian Air Force SAAB 105E crashed near Steinberg, Lower Austria, on the Allentsteig military exercise range. Flying at low airspeed in the approach configuration with the undercarriage down at only 500 ft (150 m), the pilot, Lt Thomas Ploder, lost control of the aircraft and ejected while the aircraft was at around 90º to the ground. He survived without injury. (*Air Forces Monthly)* Still in April, on the 30 th to be exact, a Spanish Air Force SRF-5A crashed during a display practice for the airbase's airshow scheduled for 11 May 2003 at Badajoz/Talavera la Real. The aircraft entered a spin from which the pilot was unable to recover due to the low height above ground level; the pilot was killed.

On 01 June 2003, celebrating 100 years of aviation achievement, a Swedish pilot, Pierre Hollander, 59, died after his aircraft, a replica of the Spirit of St Louis in which Charles Lindbergh made the first non-stop solo flight from New York to Paris in 1927, plummeted to the ground. Witnessed by approximately 8,000 thousand shocked bystanders, the replica suffered catastrophic structural failure at about 100ft (30 metres) above ground level shortly after take-off at the annual Coventry Classics (UK) airshow run by Air Atlantique. According to the AAIB, the right-hand wing suffered metal fatigue and folded back on itself as the aircraft tumbled to the ground crashing sickeningly into the top of a warehouse building on the perimeter of the field. The injured pilot was flown to hospital by air ambulance but subsequently died; there was no collateral damage or injury to spectators. The displays of vintage and classic aircraft continued following a break after the crash. Previously, a spectator was killed at the Coventry airshow in 1988, when a Gloster Meteor T7, a 1940s twin jet aircraft, crashed due to pilot error.

By the middle of the 2003 airshow season, all the signs were evident that 2003 would be another typical airshow safety year, display pilots were making the same mistakes as those of the preceding years. On 12 June 2003, a vintage Royal Navy Fairey Firefly crashed killing the pilot and passenger in front of thousands of spectators at the 'Flying Legends' airshow at Duxford's Imperial War Museum, near Cambridge. The Firefly was owned and operated by The Royal Navy Historic Flight, which operated a collection of historic British naval aircraft based at the Royal Naval Air Station Yeovilton in Somerset. The deceased were Lieutenant Commander Bill Murton, 45, (pilot) and Neil Rix, 29, (aircraft fitter).

Video footage showed the vintage aircraft entering a dive and hitting the ground away from the spectators' area in a cloud of dust and smoke as it tried to pull out of a dive. A spokesman for Cambridgeshire Fire and Rescue Service said one of the dead pilots had been found in the field where the plane crashed while the other had to be cut from the wreckage. Museum director Ted Inman said the crash on Saturday was being investigated by the Ministry of Defence. He said Duxford's accident record since it started hosting air shows in 1973 was "very good" and that Civil Aviation Authority guidelines were followed at all times. Organisers had decided to continue with the show even though it had been a "difficult call", Inman said. "Initially there was a pause because our emergency cover was away at the accident," he told a news conference.

The Fairey Firefly was a two-seat British wartime carrier-borne fighter aircraft. The prototype flew in 1941 and the type entered service in 1943 Production ceased in 1956, after around 1700 Fireflies had been built. The aircraft involved in the crash, WB271, entered RN service in 1949 and later saw service in the Korean War. It was transferred to the RN Historic Flight in 1972

The plane was conducting basic aerobatic manoeuvres in clear conditions before it rolled inverted and in the ensuring recovery pull-out, there was insufficient height to safely affect the recovery and the aircraft impacted a field close to the M11 motorway, but well away from spectators. A report from Air Accidents Investigation Branch (AAIB) issued earlier that week, recommended a review of current arrangements at Duxford airfield to prevent aircraft landing or aborting take-offs from running on to the M11. This followed an accident on June 2, 2002, when a former Soviet air force two-seat L-39 military jet trainer aircraft came to rest on the motorway after going through the boundary fence while landing at Duxford. Considering that the airshow season for world airshows centres around the six-month period May to October of each year, not a good year at all.

SOME ACCIDENTS NOT ADDRESSED

It is virtually impossible to include all airshow accidents within the confined space of a single chapter. Many more accidents were not considered, amongst others, several *Blue Angels* accidents not covered in the database include fatal accidents in 1966 during a show in Toronto and two in 1967 during practice that closed out the Grumman Tiger's otherwise successful twelve-year tour of duty with the *Blue Angels* . A series of three tragic accidents in 1972 and 1973 resulted in the *Blue Angels* leaving the Phantoms by 1974 for the A-4 Skyhawk while further fatal airshow accidents in 1978, 1981 and 1985 resulted in the acceleration of a transition to the F/A-18 Hornet.

On 31 August 2001, a Belgian Army Alouette II crashed following engine failure shortly after take-off during a Family Open Day at Liege-Bierset Air Base. An elderly man, the father of a soldier at the base, was killed and the other three on boards were seriously injured. *(Air Forces Monthly)*

In 2002 there were several accidents that were not included but which actually increased the number of accidents for 2002 to more than twenty. On 25 February 2002, Brazilian aerobatic pilot, Paulo Henrique, successfully bailed out of his Extra 230 when, during a practice session, he noticed a vibration on the stick that ended in a total loss of the left aileron. Not being able to gain control of the aircraft which was in a dive, he made a quick and smart decision to bail out at 1,000 ft agl and landed safely without injury.

On 4 May 2002, a Stearman PT-17 biplane lost power and crashed while performing at the Georgetown (Texas) Air Show. Pilot Harold Smith and a passenger walked away from the wreckage after the aircraft lost power shortly after take-off. After hitting telephone lines and a tree, the Stearman crashed into the garage of an unoccupied home near the airport. No one in the aircraft or on the ground was hurt in the accident, although the aircraft was completely destroyed.

In the UK, the pilot of a Tiger Moth escaped serious injury when his aircraft crashed to the ground at a charity Airshow on 21 July 2002. The 55-year-old pilot was thrown clear of the wreckage of the plane when it plunged 300ft to the ground at the White Waltham airfield near Maidenhead, Berkshire. Thames Valley Air Ambulance crew, who the pilot was raising money for, were on standby at the display and flew the pilot to the Wexham Park Hospital in Slough.

SNJ pilot Bob Beckman, a member of the Historical Aircraft Squadron, was killed on, 29 September 2002 in Circleville, Ohio, while flying in formation with two other Texans at a Fly-In. Witnesses said the aircraft pitched upward and them plunged into the ground.

Some of the accidents of the South African Air Force not addressed over the years, include an Aermacchi MB-326M from CFS Langebaanweg flown by Capt Les Marshall that crashed while performing a low-level Derry-Turn at Summersfield (Western Cape) in 1973 in preparation for an upcoming airshow. An Aermacchi MB-326K flown by Capt 'Mac' McCloud crashed during a low-level, undercarriage down roll and another MB-326K flown by Capt Richard Miller, crashed during a one-and-a-half roll from inverted. All were fatal accidents that occurred while practicing for an airshow, all experienced operational pilots and each with several hundred of hours on type. Then of course, there was also the case of a pilot from the Harvard Club of South Africa at an airshow in Pietersburg in 1996. The pilot did not pick the nose up high enough prior to commencing the roll and 'mushed' into ground while conducting an impromptu aileron roll on departure after the airshow. What is pertinent to note that in the previous four accidents mentioned, the cause was low-level rolling manoeuvres, not vertical manoeuvres.

Although the Paris Airshow has historically had some nasty accidents, so has Farnborough. In the mid 1970's a Gyrocopter at Farnborough International gave a highly dynamic display but the pilot (a fixed wing pilot), lost control and used incorrect techniques to recover. In a co-ordinated- synchro display at Farnborough between a Viggen and a SAAB105 in the mid 70s, the SAAB 105 did a wheels-up landing. In the mid-1990's, an Su-27 ran off the end of the runway following an instruction to land by the Flying Control Committee because the practice display was apparently all over the place with several contraventions of the display arena. The aircraft touched down fast with more than two-thirds of the runway behind the aircraft! On questioning the pilot about the deep touch-down, he answered: “but you said land immediately – so that’s what I did!”

The loss of an aircraft in an air force’s prestige aerobatic team is always especially sensitive to the particular armed force since most air components advertise their national formation aerobatic teams as representing the best of the flying skills of the force; it epitomises the skills of the force’s best. Any negative aspects impact adversely on the public image of their pilot’s abilities. However, this certainly doesn’t have to be like that, after all, nearly all airshow accidents in the world have involved some of the world’s most experienced pilots. The sooner it is realised that airshow accidents are not the sole right of inexperienced pilots, that airshow accidents don’t discriminate, the better for a mature understanding of the hazardous nature of low-level display flying.

Although national formation aerobatic teams pilots are chosen for their above average flying abilities, they are all susceptible to human error as much as any other Service pilot. While the teams may undertake many hours of intensive practice in the skills of close formation aerobatics, they are also required to maintain their currency, through instrument flying, emergencies and simulator training. Even if errors or accidents occur outside of the public scrutiny, the tolerance level for errors is extremely tight and it is not uncommon for members to be dismissed from the team or resign from the Service following an accident – its just that kind of pressure from performing at the highest professional level.

Between 1965 and 1971, the *Red Arrows* lost six aircraft due to a variety of causes, and all during the winter practice period. Three of the losses occurred during 1969, the first in March when a Gnat impacted with the ground at the bottom of a loop and then again two in December in a freak occurrence. One of the team reported a fire from the tailpipe of one of the Gnats during a formation practice. Unfortunately, two pilots, both having heard the fire warning, each assumed that it was their aircraft that was on fire, left the formation and ejected, fortunately without injury. In 1970, another Gnat was lost when the pilot ejected during a practice session following an engine failure but it was two months later that the worst *Red Arrows* accident occurred. It was on 20 January 1971, while flying the Carousel, the synchro-pair collided head-on, killing four pilots.

Only two *Red Arrows* accidents occurred during actual displays, neither of which caused injury to the pilots or the spectators. The first accident, incidentally the first Hawk loss, occurred during a display over the Brighton sea front on 17 May 1980. After breaking away from the main formation, the synchro-pair began a series of opposition passes along the display line chosen over the sea, parallel to the coastline and between the Palace and West Piers. On the fourth opposition pass, No. 2 struck the mast of a yacht which, unnoticed, had motored slowly on to the previously clear display line. The yacht carried no sail at the time; the pilot, Sqn Ldr Johnson, ejected just three seconds after the collision with the aircraft out of control and almost inverted and no more than 300 feet above sea-level.

The authorised minimum height for the synchro pair at the time was 35 feet, a height considered to give a safe clearance and provide a spectacle for the public. There was no embargo on boat movements during the display and therefore no reason for the skipper of the yacht to suspect that his passage would obstruct the synchro-pair. The pilot did no see the slow-moving obstruction against the vertical pier structure and the sea, and his aircraft struck the mast just four feet below its tip. Immediately after the accident, the minimum height for all *Red Arrows* displays was raised to 100 feet.

The circumstances of the second display accident were more mundane, if engine failure can be described as ‘mundane’. On the evening of 31 August 1984, the team was performing over the sea-front at Sidmouth (UK). As the main formation approached the top of a Vixen loop, the engine of the No 8 aircraft piloted by Flt Lt Pete Lees, positioned on the rear right hand side of the main formation, surged due to low pressure compressor blade failure. The surge could not be rectified and the pilot ejected successfully. Once again in 1986, *Red 8* suffered an engine failure on 3 November 1986 during a practice over the airfield at RAF Scampton, Lincolnshire. With the engine flamed-out and no relight achieved, the aircraft undershot the runway from the forced landing pattern and the pilot, Flt Lt Dean Findlay, ejected successfully, at a very late stage.

Also in 1984, in fact on 21 March, while the *Red's* were preparing for dress rehearsals in Cyprus, during the final manoeuvre of the synchro-pair, the opposition loop, Synchro 2 struck the ground on the pull-out. Starting with the 100 ft opposition pass, the synchro-pair pulled up into the loop to cross at the top in an inverted position, and then cross-over during the pull-out prior to achieving a 'crowd departure gate'. On this occasion, it became apparent to both pilots that Synchro 2 was higher than Synchro 1 at the inverted position. In an effort to balance the formation, Synchro 2 pulled much tighter than Synchro 1 on the descent resulting in a much steeper descent angle and insufficient altitude to complete the recovery dive. The aircraft hit the ground in a near level attitude and bounced several times; the ejection seat was forced up on its rails and through the canopy on initial impact leaving the pilot, Flt Lt Hirst, exposed to the airflow.

The second bounce breached the seat firing mechanism, rendering it useless. By this stage, however, the force of impact had triggered automatic man-seat separation so that at the apogee of the aircraft's second bounce, the main parachute deployed to drag the pilot clear of the disintegrating Hawk and lower him quickly to the ground. The aircraft continued to a third and final impact where it broke-up and caught fire. Flt Lt Hirst suffered major injuries but survived. The Accident Investigation Board concluded that the accident resulted from the pilot over-concentrating on achieving the correct cross-over position without appreciating the effect of pulling tighter on the aircraft's overall trajectory. After the inverted cross-over, his immediate concerns had been to achieve a smoothly consistent smoke trail and a precise departure point. His proximity to the ground and the general geometry of the descent had been a lesser consideration.

Then there was the accident almost a year later on 16 November 1987, Sqn Ldr Miller was leading a routine formation practice in the Scampton local area when, during a turn at 1,500 feet, he called for airbrake. When Flight Lt Spike Newbery, flying No. 2 in line-astern selected his airbrake, nothing happened. Despite pulling the power back, the No. 2 slid under the leader and the two aircraft collided. Both pilots immediately ejected, both suffering serious injuries. One aircraft crashed into a field while the second fell onto a row of houses in the village of Melton and although several were occupied, no one was injured on the ground.

During the filming of a *Red Arrows* takeoff for a children's TV programme called "Blue Peter" in the mid 80s, one of the pilots omitted to check that the airbrake was retracted before takeoff. The airbrake extension caused the lip of the airbrake to scrape the ground; the pilot found the effectiveness of the airbrake under such conditions quite spectacular and elected to eject on the take-off, the aircraft sliding to a halt in the runway overrun.

In an effort to attract spectators to airshows and provide a high level of entertainment, airshows have expanded their programmes to include a host of 'aviation' related events, and in some cases, even some non-aviation events. Some airshows include radio controlled and remotely piloted vehicle demonstrations, which must also be subjected to the same safety scrutiny as for aircraft. It is very easy to 'look down' on the scale model flyers 'toys' not realising that the momentum of current models is more than enough to fatally wound bystanders.

At least one person, a teenage girl, was injured after a radio-controlled model went out of control at an Australian airshow on 13 April 1998. The model was being started up for a flight at the Mangalore Airshow, north of Melbourne, when the owner, 66-year-old George Markey, lost control of it and it skidded into the crowd. About 600 people watching the airshow fled in all directions as it ploughed across the field. Spectators had no warning of the impending danger, said a witness: "I thought it was going to get airborne, but then it crashed into the crowd and everyone started running in all directions." Some airshow attendees even tried to stop the out-of-control model after it hit and injured the girl. Luckily for the girl and the other spectators, the aircraft's propeller was in the rear, and not on the nose. "If the propeller had been on the nose of the aircraft, I would say that there would have been more people injured, really," he said.

CONCLUSION

The bottom line is this: "It doesn't matter how much experience you have, it doesn't matter who you are, whether you are from a civilian or military background, whether you are flying a vintage aircraft or the most modern fighter, whether you are flying at a top international airshow or some local village motor rally. What does matter is the energy management at each point of each manoeuvre versus the height above ground level; you're only as good as your current performance and all the experience in the world is no guarantee of survival if the pilot is not current in the specific aircraft flying a disciplined and planned show routine – its as simple as that! These accidents bring to mind the old adage taught by airshow display veterans: “Warning to pilots, fly in the middle of the airspace, the edges are defined by hard ground or sea”.

“Life is measured not by the number of breaths we take, but by the moments that take away our breaths. An airshow is normally a time of celebration, not grief. As we each deal with our own feelings, let us remember the families of each of these men”. (Captain Jim Rainwater)

CHAPTER 3

AIRSHOW ACCIDENTS DATABASE AND STATISTICAL ANALYSIS

Patrouille de France synchronous pair crossing during the opposition pass at the Chateaudun AFB national airshow, 10 May 2003. (Antoine Grondeau)

"The ideal display pilot is the perfect blend of discipline and aggressiveness." (Anon)

Pilots do not intentionally aim to crash during display flying; the environment is hostile and any lapse in concentration by the pilot, misjudgement, poor anticipation, mechanical failure or rash indiscipline, may result in a crash. In many cases it is easy to lay blame on the pilot, but one must get to understand the underlying reasons why the pilot made a mistake, a mistake which in most cases, cost lives. The survival instinct of the human is an incredibly strong motivator in avoiding crashes, no pilot deliberately crashes an aircraft - so what is it that causes the pilot's physiology to be seduced by peripheral inputs? What is it that convinces the pilot that the selected course of action would offer the best results and survival index?

The old adage "if you cannot express it in numbers, you don't understand it" is particularly relevant in better understanding the hazards imposed by low-level display flying. To this end, a random sample of 118 airshow accidents worldwide, extending over the fifty-year period from September 1952 to November 2002, is included in Table 1. The sample range is by no means comprehensive and considers 57 current military and 61 civilian and military museum airshow accidents. Each accident has been considered in terms of aircraft type, category, causal factors, fatalities, ejection, whether the accident occurred during a display practice or airshow and finally location. The analysis does not attempt to apportion blame, but only to tabulate the relevant accident detail for the purpose of analysis of the sample data in an attempt to determine trends in airshow accidents and not necessarily absolute values.

Table 1. Database of Random Selection of Airshow Accidents: 1952 – 2002

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
1	06 Sep 1952	De Havilland DH110	Fighter	Mechanical (Structural) Climbing Roll	1 Pilot 1 Crew 28 Spectators 63 Injured	2 No	Air Show	Farnborough, United Kingdom
2	03 Jun 1961	B-58 Hustler (USAF)	Bomber	FIT (Roll) Weather (Cloudbase)	1 Pilot 2 Crew	3 No	Air Show	Paris Air Show, France
3	16 Jun 1963	Hawker Siddeley P.1127	Fighter (Prototype VSTOL)	Mechanical (Engine)	0	N/A	Air Show	Paris Air Show, France
4	19 Jun 1965	Fiat G-91 (Italian Air Force)	Fighter	Loss of Control (Landing)	1 Pilot 9 Spectators	No	Air Show	Paris Air Show, France
5	04 June 1967	Fouga Magister Patrouille de France (French Air Force)	Trainer Jet	FIT (Bombburst)	1 Pilot	No	Air Show	Paris Air Show, France
6	20 Jan 1971	2 x Hawk T Mk 1 Red Arrows RAF	Trainer Jet	Mid-Air Collision (Opposition Pass)	4 Pilots	4 No	Display Practice	RAF Kemble, United Kingdom
7	04 June 1972	F-4 Phantom Thunderbirds (USAF)	Fighter	Loss of Control (Run-in Break)	1 Pilot (Ejection into Fireball)	Yes	Air Show	Transpo 72, Dulles, USA
8	06 Mar 1973	Tupolev Tu-144 (Aeroflot)	Transport (Civil Airliner)	Loss of Control (Climb)	2 Pilots 4 Crew 8 Public + 60 Injured	N/A	Air Show	Paris Air Show, France
9	01 Sept 1974	Sikorsky S-67 Blackhawk	Helicopter	FIT (Roll)	2 Pilots Injured + 1 Aircrew	N/A	Air Show	Farnborough, United Kingdom
10	30 Apr 1975	BAe Jaguar T.2 (Royal Air Force)	Trainer Jet (Ground Attack)	FIT Maintenance (Inverted Flight)	0	Yes	Display Practice	RAF Lossiemouth, Scotland
11	08 Oct 1977	Britten-Norman Trislander	Transport (Light Utility)	FIT (Loop) Weather	1 Pilot Injured + 1 Pax	N/A	Air Show	Lanseria, South Africa

				(Density Alt)	Injured			

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
12	03 Jun 1977	Republic A-10 Thunderbolt (USAF)	Fighter (Ground Attack)	FIT Weather (Loop)	1 Pilot	No	Air Show	Paris Air Show, France
13	10 Oct 1981	Pitts Special	Sport (Aerobatic)	FIT (Inverted Spin)	1 Pilot Injured	N/A	Air Show	Lanseria, South Africa
14	18 Jan 1982	4 x T-38 Talon Thunderbirds (USAF)	Trainer Jet	FIT (Loop)	4 Pilots	4 No	Display Practice	Nevada, USA
15	11 Sept 1982	Chinook (United States Army)	Helicopter	Mechanical (Structural Failure)	2 Pilots 3 Aircrew 41 (Pax) Parachutists	N/A	Air Show	Mannheim, Germany
16	27 May 1983	Transall C-160 (SAAF)	Transport (Medium Lift)	Wheels-Up Landing (Short-Field Demo)	0	N/A	Display Practice	AFB Waterkloof, South Africa
17	10 Oct 1984	Northrop F-20 Tigershark	Fighter	FIT (Climbing Roll)	1 Pilot (Outside Ejection Envelope)	Yes	Air Show	Suwon, Korea
18	04 Sep 1984	De Havilland Buffalo	Transport (Medium Lift)	Loss of Control (Approach)	2 Pilots Injured 1 Pax Injured	N/A	Air Show	Farnborough, United Kingdom
19	14 May 1985	Northrop F-20 Tigershark (Northrop)	Fighter	FIT (Climbing Roll)	1 Pilot	No	Display Practice	Goose Bay, Labrador, Canada
20	15 Dec 1985	2 x MB 326H Roulettes (RAAF)	Trainer Jet	Mid-Air Collision	2 Pilots	Yes No	Display Practice	RAAF East Sale, Victoria, Australia
21	13 Jul 1985	2 x A-4 Skyhawk Blue Angels (US Navy)	Fighter	Mid-Air Collision (Opposition Pass)	1 Pilot 0	No Yes	Air Show	Niagara Falls, USA
22	10 Mar 1988	2x MB 326H Roulettes (RAAF)	Trainer Jet	Mid-Air Collision	0	Yes No	Display Practice	RAAF East Sale, Victoria, Australia

23	16 Apr 1988	Aermacchi MB-326M Silver Falcons (SAAF)	Trainer Jet	Mechanical (Engine Fire)	0	Yes	Air Show	Stellenbosch, South Africa
24	24 Apr 1988	McDonnell Douglas F-18 (USMC)	Fighter	FIT (Loop)	1 Pilot injured	No	Air Show	El Toro, California, USA
25	26 Jun 1988	Airbus A320 (Air France)	Transport (Civil Airliner)	FIT (Flight Control System)	3 Pax Killed + 50 Pax Injured	N/A	Air Show	Mulhouse-Habsheim, France

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
26	28 Aug 1988	3 x MB 339 Frecce Tricolori, (Italian Air Force)	Trainer Jet	Mid-Air Collision	3 Pilot + 69 Spectators + 300+ Injured	3 No	Air Show	Ramstein AFB, Germany
27	09 Jun 1989	MiG-29 (Mikoyan)	Fighter	Mechanical (Engine) High Alpha Fly-By	0	Yes	Air Show	Paris Air Show, France
28	17 Jun 1989	North American AT-6D	Vintage Propeller (Trainer)	FIT (Roll from inverted)	1 Pilot	N/A	Display Practice	Earle, Arizona, USA
29	03 Sep 1989	2 x CT-114 Snowbirds (RCAF)	Trainer Jet	Mid-Air Collision (Bombburst)	1 Pilot + 1 Pilot Injured	Yes No	Air Show	Lake Ontario, Toronto, Canada
30	08 Oct 1989	Mirage 2000 (Indian Air Force)	Fighter	FIT (Downline Rolls)	1 Pilot + 2 Public + 20 Injured	No	Air Show	New Delhi, India
31	24 Oct 1989	2 x A-4 Skyhawk Kiwi Red (RNZAF)	Fighter	Mid-Air Collision (Roll-Under Break)	1 Pilot	No	Display Practice	Raumani Range, New Zealand
32	23 Jan 1990	2 x F/A-18 Hornet Blue Angels (USN)	Fighter	Mid-Air Collision	0	Yes	Display Practice	El Centro, California, USA
33	02 May 1993	Canadair F-86E Sabre	Vintage Jet (Fighter)	FIT (Loop)	1 Pilot	N/A	Air Show	MCAS El Toro, California, USA
34	26 Jun 1993	Boeing PT-17 Stearman	Vintage Propeller (Trainer)	Loss of Control (Roll)	1 x Pilot 1 x Crew Wingwalker	N/A	Air Show	Concord, New Hampshire, USA
35	24 Jul 1993	2 x MiG-29 Mikoyan	Fighter	Mid-Air Collision (Loop) Weather	0	2 Yes	Air Show	RAF Fairford, United Kingdom
36	08 Aug 1993	SAAB JAS-39 Gripen (Swedish Air Force)	Fighter	Mechanical (Flight Control System)	0	Yes	Air Show	Stockholm, Sweden

37	02 Oct 1993	Aermacchi MB-326M Silver Falcons (SAAF)	Trainer Jet	Mechanical (Structural Wing)	1 Pilot Outside Ejection Envelope	Yes	Air Show	Lanseria, South Africa
38	14 Feb 1994	Lockheed Martin F-16 Thunderbirds (USAF)	Fighter	FIT (Spiral Descent)	1 Pilot Injured	No	Display Practice	Nevada, USA
39	24 Jun 1994	Boeing B-52 (USAF)	Bomber	Loss of Control (Steep Turn Weather)	2 Pilots 2 Crew 1 Outside Ejection Envelope	1 Yes 3 No	Display Practice	Washington State, USA

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
40	17 Jul 1995	2 x Aero L-39 Albatross White Albatross (Slovak Air Force)	Trainer Jet	Mid-Air Collision	0	2 Yes No	Display Practice	Kosice, Slovakia
41	09 Sep 1995	Messerschmitt Bf-108	Vintage Propeller (Liaison)	FIT (Roll)	1 Pilot 1 Pax	N/A	Air Show	Berlin Johannistal, Germany
42	02 Sep 1995	BAe Nimrod (Royal Air Force)	Transport (Maritime Patrol Aircraft)	FIT (Wingover)	2 Pilots 5 Aircrew	N/A	Air Show	Toronto, Canada
43	27 Sep 1995	B-26 Marauder	Vintage Propeller (Bomber)	Mechanical (Engine)	2 Pilots 1 Crew 2 Pax	N/A	Display Practice	Odessa, Texas, USA
44	8 Nov 1995	2 x Pilatus PC7 Mk II Astra (SAAF)	Trainer Turboprop	Mid-Air Collision	0	1 Yes	Display Practice	CFS Langebaanweg, South Africa
45	16 Apr 1996	Hawker Sea Fury	Vintage Propeller (Fighter)	Loss of Control (Landing)	1 Pilot	N/A	Air Show	EAA Lakeland Sun ‘n Fun, USA
46	05 May 1996	North American Harvard AT-6	Vintage Propeller (Trainer)	FIT (Roll)	1 Pilot	N/A	Air Show	Seratoma, Louisiana, USA
47	26 May 1996	Lockheed Martin F-16 (Portuguese AF) + BAE Hawk (RAF)	Fighter + Trainer Jet	Mid-Air Collision	0	1 Yes	Air Show	Beja AB, Portugal
48	07 Jun 1996	De Havilland 112 Venom	Trainer Jet	Loss of Control (Take-off Rotation)	0	No	Air Show	Hawarden, Chester, United Kingdom
49	19 Jun 1996	McDonnell Douglas F-18C	Fighter	FIT (Outside Loop)	1 Pilot Injured	No	Display Practice	Bethalto, St Louis, USA
50	14 Jul	P-38 Lightning	Vintage Propeller	FIT (Roll)	1 Pilot	N/A	Air Show	Duxford, United

	1996	(Duxford Collection)	(Fighter)					Kingdom
51	21 Jul 1996	De Havilland DH 98 Mosquito (British Aerospace)	Vintage Propeller (Bomber)	Loss of Control (Wingover)	1 Pilot 1 Crew	N/A	Air Show	Barton, Manchester, United Kingdom
52	04 Aug 1996	Pitts Special S-1	Sport (Aerobatic)	Mechanical (Structural)	1 Pilot	N/A	Air Show	Pennsylvania, USA

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
53	01 Jun 1997	North American F-86 Sabre	Vintage Jet (Fighter)	FIT (Loop)	1 Pilot	N/A	Air Show	Denver, Colorado, USA
54	14 Jun 1997	Westland Lynx S-170 (Danish Navy)	Helicopter	FIT (Wingover)	1 Pilot Injured	N/A	Air Show	Goraszka Air Picnic, Warsaw, Poland
55	21 Jun 1997	Sukhoi Su-27 Flanker Russian Knights (Russian Air Force)	Fighter	Wheels-Up Landing	0	N/A	Air Show	Bratislava, SIAD '97, Slovakia
56	22 Jun 1997	2 x Formula V Homebuilts	Sport Experimental	Mid-Air Collision (Racing)	1 Pilot 1 Pilot Injured	N/A	Air Show	Long Island, New York
57	26 Jun 1997	AT-3 Trainer (ROCAF Thunder Tigers Team)	Trainer Jet	FIT	1 Pilot	No	Display Practice	Tapel/ KangShan AFB, Taiwan
58	26 Jul 1997	Extra 300 (Royal Jordanian Air Force)	Sport (Aerobatic)	Loss of Control (Lomcevak) Weather	1 Pilot 9 Spectators killed + 40 injured	N/A	Air Show	Ostende Flanders 'Fly-In', Belgium
59	14 Sep 1997	F-117A Nighthawk (USAF)	Fighter	Mechanical (Structural)	0 4 Public injured	Yes	Air Show	Baltimore, Maryland, USA
60	20 Sep 1997	Pitts Special S-24	Sport Aerobatic	FIT (Loop)	1 Pilot	N/A	Air Show	Confederate Air Force, Texas, USA
61	12 Oct 1997	Messerschmitt Me-109 (Imperial War Museum Collection)	Vintage Propeller (Fighter)	Mechanical (Engine)	0	N/A	Air Show	Duxford, United Kingdom
62	01 Mar 1998	Air Tractor 802A	Crop Sprayer	Loss of Control	1 Pilot	N/A	Air Show	Australia
63	19 Mar	Piston Provost	Vintage Propeller	FIT (Stall	1 Pilot	N/A	Display	AFB Swartkops,

	1998	(SAAF Museum)	(Trainer)	Turn) Weather			Practic e	Pretoria, South Africa
64	19 Apr 1998	2 x Boeing PT-17 Stearman (Red Baron Squadron)	Vintage Propeller (Trainer)	Mid-Air Collision	2 Pilots 2 Police Officers	N/A	Air Show	Florida, USA
65	21 Apr 1998	Starlight Warp Ultralight	Sport (Ultralight)	Loss of Control (Turn)	1 Pilot	N/A	Air Show	Sun ‘n Fun Lakeland, Florida, USA

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
66	08 May 1998 :	2 x Cessna A-37B Royal Black Eagles (Korean Air Force)	Trainer Jet	Mid-Air Collision	1 Pilot	No	Display Practice	Korea
67	05 Jun 1998	Hawker Hunter F4	Vintage Jet (Fighter)	Mechanical (Engine Fire)	1 Pilot	No	Display Practice	Dunsfold, United Kingdom
68	23 Jul 1998	MiG-29 Hungarian Air Force	Fighter	FIT (High Alpha Turn)	1 Pilot (Outside Ejection Envelope)	Yes	Display Practice (Media Demo)	Hungary
69	19 Sep 1994	2 x AT-6 Harvard	Vintage Propeller	Mid-Air Collision (Racing)	1 Pilot 1 Pilot Injured	N/A	Air Show	Reno Races Nevada, USA
70	15 Sept 1998 :	3 x Chengdu F-7 August 1st Aerobatic Team (Chinese PLA)	Fighter	Mid-Air Collision	3 Pilots	3 No	Display Practice	Tianjin, China
71	10 Dec 1998	2 x CT114 Tutor Snowbirds (RCAF)	Trainer Jet	Mid-Air Collision	1 Pilot (Outside Ejection Envelope)	Yes	Display Practice	Moose Jaw AFB, Canada
72	25 Apr 1999	2 x Lockheed Martin F-16 Thunderbirds (USAF)	Fighter	Mid-Air Collision	0	N/A	Air Show	Patrick AFB, Florida, USA
73	30 May 1999	Wirraway	Vintage Propeller (Trainer)	Loss Control (High Alpha)	1 Pilot 1 Pax	N/A	Air Show	Nowra, New South Wales, Australia
74	06 Jun 1999	BAE Hawk 200	Fighter	FIT (Loop)	1 Pilot 1 Spectator 4 Public injured	No	Air Show	Bratislava, SIAD ’99. Slovakia
75	12	Sukhoi Su-	Fighter	FIT	0	2 Yes	Air	Paris Air

	Jun 1999	30 MKI (Sukhoi)		(Descending High Alpha Rolls)			Show	Show, France
76	19 Jun 1999	North American F-86 Sabre	Vintage Jet (Fighter)	Loss of Control (Engine Compressor Stall)	1 Pilot	N/A	Air Show	New Jersey, USA
77	02 Aug 1999	F-4U Corsair	Vintage Propeller (Fighter)	Collision (Communic-ation)	1 Pilot injured	N/A	Air Show	EAA AirVenture, USA

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
78	12 Sep 1999	A Cessna L-19 Birddog Cessna O-2 Skymaster	Sport (Light Utility)	Mid-Air Collision	2 Pilots	N/A	Air Show	North Hampton, Massachusetts, USA
79	19 Sep 1999	Homebuilt P-51	Sport (Aerobatic)	Mid-Air Collision	1 Pilot	N/A	Air Show	Reno Air Races, USA
80	01 Oct 1999	2 x Beech D-45 (Lima Lima Aerobatic Team)	Trainer Propeller	Mid-Air Collision (‘Pop-Top-Break’)	1 Pilot	N/A	Display Practice	Illinois, USA
81	03 Oct 1999	Oracle Turbo-Raven	Sport (Aerobatic)	FIT (Loop)	1 Pilot injured	N/A	Air Show	California Int Air Show, USA
82	28 Oct 1999	McDonnell Douglas F/A-18 Blue Angels (USN)	Fighter	FIT (Arrival Manoeuvre)	2 Pilots	No	Display Practice	Moody AFB, USA
83	09 Jan 2000	Pitts Special S-1	Sport Aerobatic	FIT (Downline Rolls)	1 Pilot	N/A	Air Show	Upland, California
84	19 Mar 2000	Lockheed Martin F-16 (USAF)	Fighter	FIT (Split-S)	1 Pilot	No	Air Show	Kingsville Naval Station, Texas, USA
85	15 Apr 2000	Spitfire Mk IX (SAAF Museum)	Vintage Propeller (Fighter)	Mechanical (Engine)	1 Pilot Injured	N/A	Air Show	AFB Swartkops, Pretoria
86	26 Apr 2000	Edge 360 (Wild Bill’s” Wild Ride)	Sport (Aerobatic)	Birdstrike	1 Pilot Injured	N/A	Air Show	Louisiana, USA
87	27 May 2000	2 x Mudry Cap 10 French Connection	Sport (Aerobatic)	Mid-Air Collision	2 Pilots	N/A	Display Practice	Daytona, Florida
88	03 Jun 2000	Aero L-39 Albatross (Slovak Air Force White Albatross)	Trainer Jet		1 Pilot	No	Air Show	Sliac Military, Slovakia

89	18 Jun 2000	Grumman F-14 Tomcat (USN)	Fighter	Loss of Control (Wave-off)	1 Pilot 1 Crew 3 Rescue Personnel injured	No	Air Show	Willow Grove, Pa, USA
90	18 Aug 2000	Aero L-29 Delphin	Trainer Jet	FIT (Downline Roll)	1 Pilot	No	Air Show	Eastbourne, United Kingdom

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
91	17 Dec 2000	Beech T-34 Mentor	Vintage Propeller (Trainer)	Loss of Control (Stall Turn)	2 Pilot 1 Public killed + 1 injured	N/A	Air Show	Izmit City, Istanbul, Turkey
92	16 Feb 2001	A-4 Skyhawk (RNZAF)	Fighter	FIT (Plugged Barrel Roll)	1 Pilot	No	Display Practice	Nowra, Australia
93	10 Apr 2001	Tutor CL-114 Snowbirds (RCAF)	Trainer Jet	Loss of Control (Formation Landing)	0	N/A	Display Practice	Vancouver Island, Canada
94	15 Apr 2001	H-4 Co-A Copter	Helicopter (Sport)	Loss of Control (Handling)	0	N/A	Air Show	Sun 'n Fun, USA
95	06 May 2001	P-51D Mustang (SAAF Museum)	Vintage Propeller (Fighter)	Mechanical Failure (Wheels Up Landing)	0	N/A	Air Show	AFB Waterkloof, South Africa
96	02 Jun 2001	De Havilland 112 Venom	Trainer Jet	Wheels Up Landing	0	N/A	Air Show	Biggin Hill, United Kingdom
97	02 Jun 2001	De Havilland Vampire T.Mk II	Trainer Jet	Loss of Control (Wake Vortex)	2 Pilots	N/A	Air Show	Biggin Hill, United Kingdom
98	03 Jun 2001	Bell P-63A Kingcobra	Vintage Propeller (Fighter)	Loss of Control (Loop)	1 Pilot	N/A	Air Show	Biggin Hill, United Kingdom
99	04 Jun 2001	Supermarine Spitfire	Vintage Propeller (Fighter)	Mechanical (Engine)	1 Pilot	N/A	Air Show	Rouen Vallee, France
100	10 Jun 2001	2 x Aero L-39 Albatross (Russian Air Force)	Trainer Jet	Mid-Air Collision	1 Pilot (Outside Ejection Envelope)	2 Yes	Air Show	St Petersburg, Russia
101	21 Jun 2001	2 x CT114 Tutor Snowbirds (RCAF)	Trainer Jet	Mid-Air Collision	0	2 Yes	Display Practice (Media)	Ontario, Canada
102	18 Jun	Fouga Magister	Trainer Jet	Mechanical	1 Pilot 1 Pax	No	Air Show	Deke Slayton Airfest,

	2001			(Structural)				Wisconsin, USA
103	09 Jul 2001	Hawker Sea Fury	Vintage Propeller (Fighter)	Loss of Control (Climbing Turn)	1 Pilot	N/A	Air Show	Sarnia, Canada
104	24 Aug 2001	North American T-6 Harvard	Vintage Propeller (Trainer)	Loss of Control (Hammer-head Stall)	1 Pilot 1 Pax	N/A	Display Practice	New Mexico, USA
105	17 Oct 2001	Edge 540	Sport (Aerobatic)	FIT (Turn Around)	1 Pilot Injured	N/A	Air Show	Jiln City, China

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
106	16 Jan 2002	Fouga Magister (El Salvador Air Force)	Trainer Jet	FIT	1 Pilot	No	Display Practice	San Salvador, South America
107	05 Feb 2002	2 x Hawk Mk 65 Green Falcons (RSAF)	Trainer Jet	Mid-Air Collision (Formation Landing)	0 4 Public injured	2 Yes	Display Practice	Tabuk Air Base, Saudi Arabia
108	08 Mar 2002	Lockheed Martin F-16A (Portuguese Air Force)	Fighter	FIT (Loop)	1 Pilot	No	Display Practice	Monte Real, Portugal
109	28 Mar 2002	2 x Hawk Mk 53 Jupiter Blue (Indonesian Air Force)	Trainer Jet	Mid-Air Collision (Roll)	4 Pilots	4 No	Display Practice	Madiun, Indonesia
110	11 Apr 2002	Alpha Jet Patrouille de France (French Air Force)	Trainer Jet	FIT (Run In Break)	1 Pilot (Outside Ejection Envelope)	Yes	Display Practice	Salon-de-Provence, France
111	20 Apr 2002	QF-4S Phantom (USN)	Fighter	Loss of Control (Run-In Break)	1 Pilot 1 Crew (Outside Ejection Envelope)	2 Yes	Air Show	California, USA
112	23 Jun 2002	AcroEz (Patrouille Reva)	Aerobatic Sport	FIT (Triple Break)	1 Pilot	N/A	Air Show	Nancy, France
113	20 Jul 2002	Alenia G-222 (Italian Air Force)	Transport Medium	Loss of Control (Short Field Landing)	0	N/A	Air Show	RAF Fairford, United Kingdom
114	27 Jul 2002	Su-27 (Ukraine Air Force)	Fighter	Loss of Control (Barrel Roll)	0 Pilot 86 Spectators 156	2 Yes	Air Show	Lviv Ukraine

					Injured			
115	02 Aug 2002	BAe Harrier GR7 (Royal Air Force)	Fighter	Mechanical (Engine)	1 Pilot Injured	1 Yes	Air Show	Stoweloft, United Kingdom
116	22 Sep 2002	Harvard Mk III (SAAF Museum)	Vintage Propeller	Mechanical (Engine)	1 Pilot Injured	N/A	Air Show	AAD 2002, AFB Waterkloof, South Africa

Ser No	Date	Aircraft Type	Category	Causal Factors	Fatalities	Ejection	Phase	Location/ Country
	a	b	c	d	e	f	g	h
117	01 Oct 2002	2 x Ilyushin-38 (Indian Navy)	Transport	Mid-Air Collision	4 Pilots 8 Aircrew 3 Public 7 Public Injured	N/A	Display Practice	Goa, India
118	10 Nov 2002	Chance Vought F-4U Corsair	Vintage Propeller (Fighter)	Mechanical (Engine)	1 Pilot	N/A	Air Show	South Carolina, USA

Note 1. Aircraft categories are divided into Fighter, Bomber, Trainer Jet, Trainer Propeller/Turboprop, Transport, Vintage Propeller, Vintage Jet, Helicopter, Glider, and Sports Aerobatic including categories up to Ultralight.

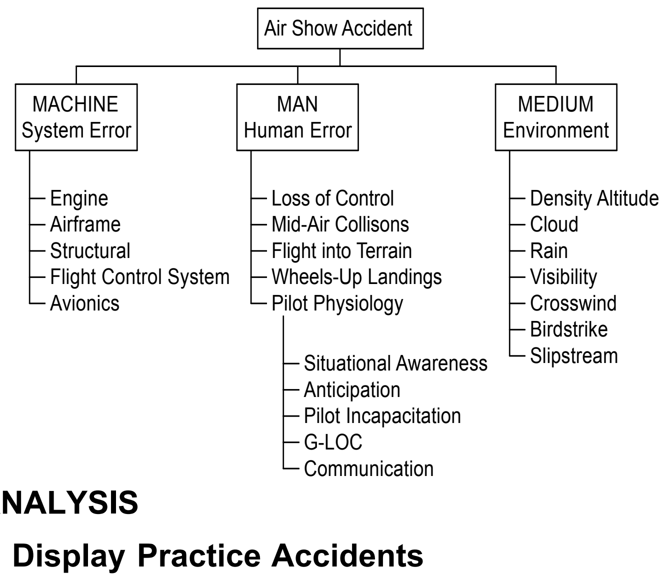
Note 2. Causal factors are considered in terms of Mechanical Failure, Flight-Into-Terrain, Mid-Air Collisions, Loss-of-Control, Wheels-up Landings and Birdstrikes.

Note 3. Ejections are considered in terms of the number of opportunities for ejection, those that ejected, those that did not eject and ejection survival rate.
Note 4. Fatalities are considered in terms of those killed or injured and then subdivided by category into pilots, aircrew, passengers, spectators and the general public. Rescue and Security personnel injuries at accidents sites are included under the category, spectator.

Note 5. Considering the foregoing, it is prudent to statistically define the accident categories in terms of the accepted convention of 3-M, ie Man, Machine and Medium.

Note 6. The occurrence of one causal factor invariably results in interaction with another of the 3-M's; there is often a secondary or 'knock-on' effect. For example, the failure of an engine (MACHINE) may lead to loss of control (MAN) if energy levels are not maintained, formation entry into cloud (MEDIUM) could lead to a Mid-air Collision (MAN); interaction between the 3M's is not necessarily a singular effect.

Fig 1. Display Flying: Causal Factors



STATISTICAL ANALYSIS

Airshow versus Display Practice Accidents

Within the scope of the analysis of 118 airshow accidents, 69% of the accident 'sample' occurred during an actual Airshow while 31% occurred during Display Practice sessions – the difference is significant (Refer Chart 1). The most probable causes of this 69:31 split can be attributed to the real world pressures of airshow display flying; the pressure to perform and to impress is higher during the actual airshow than during practice - training is unfortunately, by its inherent nature, more relaxed. This emphasises the tried and trusted military ethos to 'train as you intend to fight', which is directly applicable to display flying – 'you must train as you intend to display'. Failure to do so introduces an unknown variable into the display routine that has bearing on spectator and pilot safety. During display training, the opportunity to try again is available should a manoeuvre be 'overcooked'. During the display, however, if something goes wrong or the pilot errs slightly in any manoeuvre, there is no second chance and the pilot continues to press on to the next manoeuvre from an insecure energy baseline, possibly starting the chain of events that leads to the accident. This certainly seems to be the case in the Biggin Hill Air Fair 2001 crash of the vintage Kingcobra spinning in from the top of the loop?

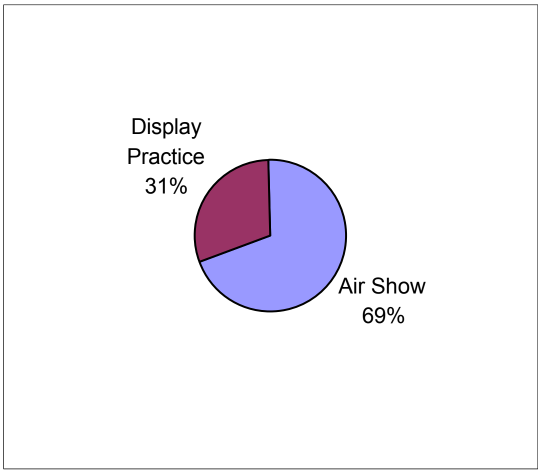


Chart 1. Airshow versus Training Accidents.

The intensity and complexity of each display practice should approximate that of the 'real' show, the pressures and stress loads should be similar. The greater the realism, the more effective the practice. It is pointless to practice under 'false' or relaxed non-realistic pressures and then only be exposed to the real world pressures on the actual show day. Once the pilot's competency has reached the required level, display practices must be as realistic as possible, the heights, positioning and the compactness must be flown as accurately as for the show day. The bad weather sequence must be flown in bad weather, right down to the worst-case 'flat show' weather requirements. If the routine was not practiced successfully, it becomes hazardous to fly the specific routine on the day of the show. It is that level of discipline that is required from professional display pilots and teams. The show day is no time to improvise or develop sequences 'on the fly'. Every practice display must be an 'actual' display.

Contributory factors include the spectator, peer and organiser pressure to perform before the public – the attitude that the 'show must go on' despite poor environmental conditions of wind, visibility, cloud, rain and density altitude – all these factors can be found as contributory causes to airshow accidents. And then of course there's the pilots ego – the desire to compete, the desire to impress, the desire to fly the best show. All demonstration pilots will have encountered this emotion and know exactly the feeling being referred to here. These factors may lead to display pilots 'pressing for maximum effect'. Not recognising that the aircraft's performance is 'maxed out', the display persists in trying to squeeze out every last bit of energy, not realising that in some occasions the conservation of energy principles require potential energy being converted to kinetic energy and the only real result at low altitude, is catastrophic.

Another observation is that most bad weather display practice usually takes place in good weather and is not necessarily given the due emphasis and respect it deserves. It is essential that 'bad weather' sequences are flown in realistic conditions. There is a recorded case in the RAF where the Station Commander questioned the rationale of the *Red Arrows* practicing in really lousy weather only

to be told that "we have to train in the most realistic conditions" – show organisers are usually loathe to cancel displays with many thousands of spectators having driven for miles and many hours to attend the popular airshows.
The reputation of the display pilot or aerobatic team is at stake and judgement often becomes blurred in the effort to accommodate and please the show organiser and the public – a good display pilot or team leader must recognise the hazards of persisting in adverse weather and make the unpopular decision if necessary, without fear of retribution. Which brings to mind the RJAF Xtra 300 crash in extreme weather conditions, rain and wind conditions that forced a large percentage of the crowd to leave and others to take refuge in the local First Aid tent – before the Xtra 300 crashed adjacent to the tent.

Airshow Accident Survivability

Within the scope of the airshow accident analysis, approximately 61% were fatal while 30% were survivable, the survival index mainly due to the aircrew ejecting. (Refer Chart 2) The remaining 9% of the accidents were 'partially survivable' and essentially includes those accidents in which at least one member of the aircrew, or one of the aircraft involved in a mid-air collision, survived. In the twenty-nine mid-air collisions between two display aircraft, in approximately 50% of the cases, at least one of the aircraft suffered catastrophic damage while the other aircraft sustained a level of damage leaving it controllable and recoverable. Survival of acrash impact obviously requires that there is no post impact fire and that the actual rate of descent at impact is absorbable by the human body. The probability of surviving an airshow accident therefore, is not high, although not impossible. The 1988 Mulhouse-Habsheim Airbus A-320 crash in the approach configuration resulted in only 3 fatalities and 50 passengers injured out of a total of 136 on-board. In this case, energy levels were relatively low and vertical descent speeds were those appropriate to the landing approach, hence at least survivable.

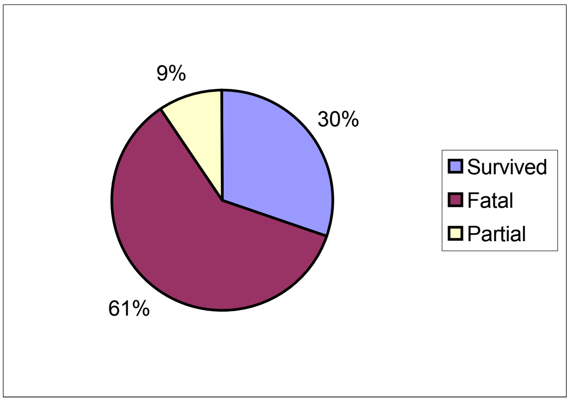
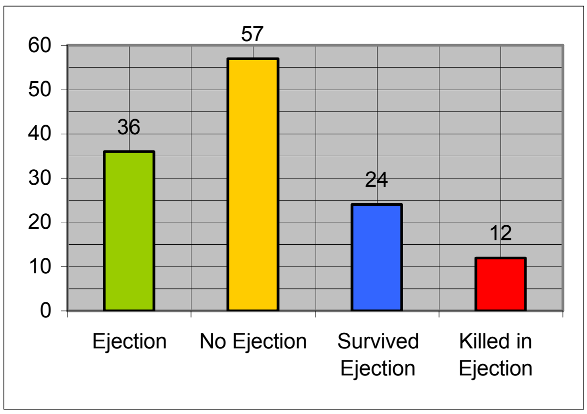


Chart 2. Airshow accident survivability.

Those cases falling into the extremely 'fortunate to survive' category include amongst others, the Sikorsky S-67 rolling accident at Farnborough 1974, the Britten-Norman Trislander 'loop' at Lanseria Airport in 1977, Nick Turvey's 'thirteen turn inverted spin' also at Lanseria in 1981, the F-18 'square-loop' at El Toro, California in 1988, the *Thunderbirds* pilot's 'spiral descent' in the Nevada Desert in 1994, the Danish Lynx S-170 'wingover' in Poland 1997 and the Corsair ground collision with a Bearcat during takeoff at EAA AirVenture,



Graph 1. Analyses of airshow accident ejections.

USA in 1999. In all the aforementioned cases, the aircraft impacted the ground with relatively high vertical or rolling energy which should in theory have resulted in fatal accidents, but didn't.
In some of the survival and partially survivable cases, the accident aircrew were able to return to flying. Kirby Chambliss, former 1998 U.S. National Aerobatic Champion and one of the world's top aerobatic pilots, ranked No 5 at the time of the accident, survived a crash into the river at Jiln City, during the Chinese Grand Prix in October 2001. The aircraft impacted into the river at approximately 200 mph (approximately 173 kts) after a "turn-around" manoeuvre and although he did not suffer any broken bones, he received several cuts to his head and face. Chambliss not only recovered from his superficial injuries, but went on to be named US National Aerobatic Champion at the US National Championships in 2002.
In another case, the F-18 crash at El Toro, USA in 1988, the damage done to the pilot's body was excessive which brought an end to his flying career. Not only did the pilot survive the crash impact from an unintentional 'square loop', but the aircraft was also restored to operational flying condition again. The crash impact loads on the body, acceleration forces and post impact fires are generally the major factors that cause the fatality. The Denel Aviation test pilot that crashed in the SAAF Museum's Piston Provost at AFB Swartkops in 1998 performing a 'stall turn', survived the initial impact but the post impact fire caused critical internal inhalation damage, the pilot passing away days later.
When considering the 'bigger picture', the role of the ejection seat as a survival enhancer, is significant. Ejection seats obviously provided the major contribution to survivable airshow accidents but unfortunately, the ejection seat is not a panacea for all conditions and has its limitations. Even so, an unacceptably high number of pilots did not make the ejection decision. The single largest factor militating against the use of the ejection seat by the pilots flying aircraft equipped with ejection seats is the inability of the human to make a timeous decision to eject.
In the analysis of 118 airshow accidents, there were 93 opportunities for ejection but only 36 (39%) ejections were actually made. (Refer Graph 1.) The question is, "why did the fifty-seven other aircrew not eject?" This question can never be answered with certainty but the dynamics of high closure rates, severe angular attitudes and decision time available to the pilot, coupled with the human's poor decision-making performance and reaction times would have contributed strongly to this phenomenon. Of the thirty-six ejections, twenty-four pilots (67%) survived. The 33% that did not survive the ejection, invariably ejected outside the ejection seat envelope being too low with either an excessive downward vector, or an extreme bank angle.
In fact, of the thirty-five ejections, seven were outside the ejection seat envelope and one was a fireball impact, a not uncommon result from extremely low-level ejections. In two fatalities, a USAF *Thunderbirds* pilot ejected into the post impact fireball at the Transpo Expo in Dulles (1972) and the USN F-4 crewmembers in April 2002 at Point Mugu (USA) airshow came very close. In the case of VSTOL aircraft, this problem is amplified. The ejection by Flt Lt Tony Cann from a Harrier GR7 on 02 August 2002 at the Lowestoft Airshow (UK) was a major let-off for the ejecting pilot.
The Harrier, hovering off the beach at approximately 100 ft suffered an engine failure and the pilot ejected at approximately 50 ft with a moderate rate of sink.

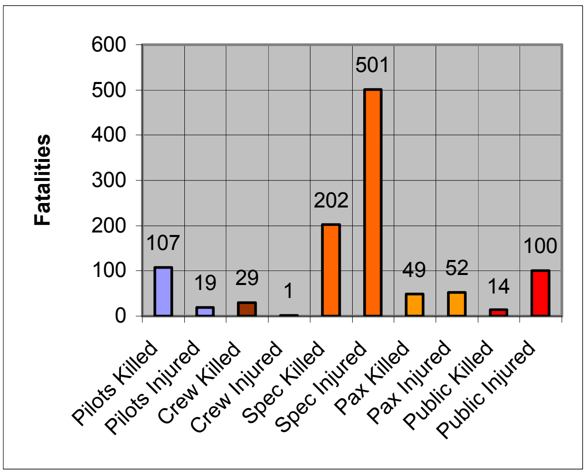
The parachute opened with sufficient time to complete only one pendulum before the pilot entered the water, landing virtually on the sinking Harrier. If the aircraft had crashed over land, any post-impact fireball would have certainly killed the pilot. From low-level ejections, the aircraft's forward travel after ejection is never too far ahead of the near-vertical trajectory of the seat occupant. The role of the prevailing wind is an extremely critical element of safe low-level ejection and an on-crash wind blowing the parachute into the fireball is a real hazard that all pilots are faced with. Importantly, the twenty-four successful ejections were mostly characterised by essentially level attitudes with positive or at worst, minimal downward vertical vectors. The classical examples of successful low-level ejections of course being the rather spectacular MiG-29 ejection at Paris Airshow in 1989, the two MiG-29 ejections at RIAT 93 (RAF Fairford, UK), the SU-30MKI, again at Paris Airshow in 1996 and the F-117 ejection following catastrophic structural failure in Baltimore, USA in 1997.

The close proximity of the ejected pilot to the aircraft impact point following a low-level ejection is clearly depicted in this MiG-29 crash at Paris Airshow in 1989. (Aviation & Week Space Technology)

The category, 'most successful airshow ejection to date' most certainly belongs to the dual ejection of the two Ukrainian Air Force pilots that ejected from the Su-27 at the world's worst airshow disaster on 27 July 2002. Both pilots ejected only after the aircraft was about to impact the ground – it had already clipped the ground with a wing before both pilots decided that the only option available for personal survival was ejection – both suffered fractured vertebrae. Ejection seats, in particular the Russian Zvezda, have provided spectacular examples of successful ultra low-level ejections and the potential for the modern ejection seat at increasing the survivability rates for display accidents.

Analysis of Airshow Accident Fatalities

Within the airshow accident population sample covered in the analysis, a total of at least 1,074 people were killed or injured in pursuance of display flying, either as pilots, aircrew, spectators, passengers or even as members of the public totally divorced from the airshow itself. (Chart 3 and Graph 2) Although the accident sample size was only 118 accidents, 107 (10%) pilots lost their lives while nineteen were injured. There were only 22 (19%) accidents out ofthe 118 in which there was no



Graph 2. Airshow accident fatalities and injuries.

significant injury to the aircrew, spectators or public. Invariably, aircrew in a display accident perished with the pilots.

One of the major concerns is the high number of spectators killed or injured while attending airshows. Within the scope of the analysis, 66% of the victims (703) were spectators, 202 killed and in excess of 501 spectators were injured while attending airshows. Even more disconcerting is the ratio of aircrew or airshow performers to spectators and public fatalities. In the analysis that equates to a ratio of 156:917 or 15% vs 85%. In the face of such statistics, the question can rightly be asked, who is at the higher risk at an airshow, the aircrew or the spectators? You decide!

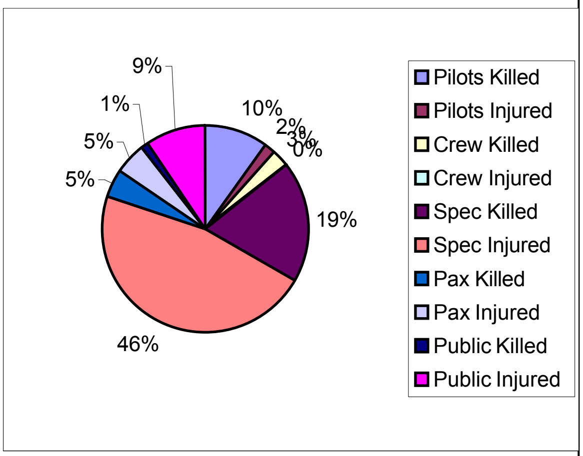


Chart 3. Airshow accident percentiles in

The major contributors to such devastating statistics were the Ukrainian Air Force's Su-27 crash into the spectator enclosures killing 83 and injuring 156 spectators in July 2002. The *Frecce Tricolori* accident at Ramstein AB in Germany in 1988 (69 killed and more than 300 injured), the Royal Jordanian Air Force Xtra 300 that crashed adjacent to the First Aid tent at the 'Flanders Fly-In' in 1997 (9 killed and 40 injured) and also John Derry'sSea Vixen accident at Farnborough in 1952 (28 killed and 63 injured) are just some of the display accidents that have claimed the lives of airshow spectators.

The imposition of safety regulations by show organisers and the compliance with such regulations by the display pilots is essential to reduce this unacceptably high percentage of airshow fatalities. Failure to do so poses a serious threat to the future continuance of airshows that have already been hit by the extremely high insurance and security costs.

The hazards facing spectators at airshows are generally known and regulations are imposed to address spectator safety, however, in the case of the general public not even involved with the airshow, there is no elegant solution. The concerns by inhabitants of housing estates around the airfield are certainly well founded with added housing insurance implications. The area in and around an airfield being used for an airshow is at risk to collateral damage in the event of an aircraft crashing outside of the display arena or airfield. In the analysis, fourteen members of the public were killed and one hundred were injured – members of the public that just happened to be in the wrong place at the wrong time, were killed or injured by airshow crash debris.

The innocent bystanders, the public killed or injured by collateral airshow accident damage, is pertinently illustrated in the case of the Tupolev Tu-144 accident at the Paris Airshow in 1973 in which eight members of the public were killed and sixty injured by crash debris coming down on the village of Goussainville, a few miles from the Le Bourget airport. Also, the Indian Air Force Mirage 2000 crash in Delhi in 1989 not only claimed the lives of two spectators, but also injured twenty members of the public outside the airfield. The USAF F-117 catastrophic in-flight break-up at an airshow in Maryland, USA during September 1997 resulted in injury to four members of the public and also to several homes, fortunately, the residents were not at home at the time of the accident. In October 2002, two Indian Navy IL-38 maritime patrol aircraft in formation practicing for an airshow to mark the 25 th anniversary of the Indian Navy's 315 Squadron, collided in mid-air in the western state of Goa. One of the aircraft impacted on a road and the other on a building construction site, all twelve aircrew died while crash debris killed three labourers and injured seven.

In terms of passenger fatalities, 49 passengers were killed and 52 injured in airshow accidents. The major contributor to passenger statistics was the 1988 Mulhouse-Habsheim Airbus A-320 crash in the approach configuration, which resulted in 3 fatalities and 50 passengers injured out of a total of 136 on-board. In this case, energy levels were relatively low and vertical descent speeds were those appropriate to the landing approach, making the crash survivable, at least. Correctly or incorrectly, the statistics of the US Army Chinook accident in 1982 with 41 Skydivers on-board was, due to lack of adequate definition, included as 'passengers which inflated the passengers killed statistics. In strict accordance with aircrew definitions, skydivers are not considered as aircrew, but rather in this specific instance, 'passengers-on-duty'. Two enthusiastic aviation photographers from the UK were killed in the crash of the sole airworthy B-26 Marauder during a display practice at Odessa, Texas in 1995 while a passenger was killed in the Wirraway accident at Nowra, Australia (1999) and another was killed in June 2001 in a Fouga Magister at Deke Slayton in Wisconsin. An astronaut died in the Bf-108 airshow accident at Berlin Johannistal Germany in 1995. Fortunately, the passengers in the Britten Norman Trislander crash at Lanseria, South Africa in 1977 and in the De Havilland Buffalo crash at Farnborough in 1994, suffered injuries only.

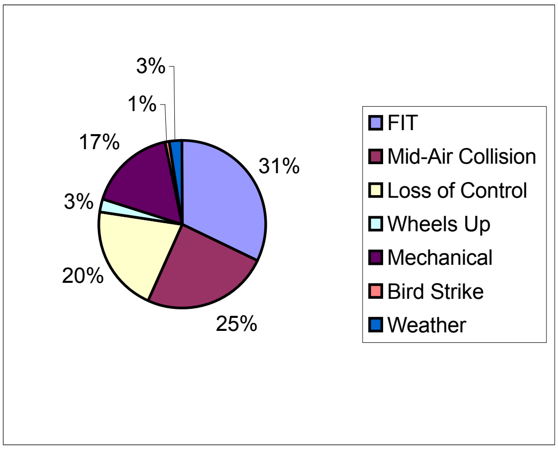


Chart 4. Percentiles of accident causal factors.

In terms of litigation, this is obviously not normally an issue within military circles since military personnel would have the necessary authority and insurance cover. However, in modern regulatory society, any proof of negligence would most definitely provide the basis for claims against the Company, the Service or even the display pilot. The prudent rule of thumb remains, no passengers should be allowed to participate in flight displays unless essential to the safe operation of the aircraft, and then only once all the legal aspects have been covered.

Analysis of Accident Causal Factors

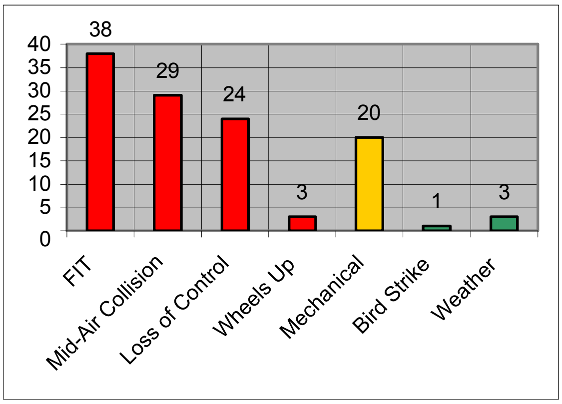
Analysis of the sample data clearly illustrates that the highest percentage of accidents can be attributed to Man, 79% (Chart 4). Man's weaknesses are accentuated in the categories of accidents represented by human error, more specifically, Flight-Into-Terrain (31%), Mid-Air Collisions (25%), Loss-of-Control (20%) and Wheels-Up-Landings (3%). MACHINE's contributions of Mechanical (17%), Weather (3%) and Birdstrikes (1%) make up the remaining 21%. Although Man's contribution to airshow accidents is a staggering 79%, considering the hostile environment of the low-level display arena and the human's physiological shortcomings, certainly not surprising.

In the real world, there is a fine line between the definitions of Flight-into-Terrain (FIT) and Loss-of-Control (LOC). FIT considers those accidents where the aircraft impacted the ground at high energy levels, those typically associated with not recovering from a low-level vertical or rolling manoeuvre, for whatever reason. Loss-of-Control on the other hand, is associated with the low airspeed, high angle of attack flight regime manifested as departures and spins - the pilot losing control of the aircraft for whatever reason.

Of the 38 FIT accidents, twenty-seven accidents (71%) were in the vertical while only six (16%) were associated with low-level rolling manoeuvres. The remaining 13% typically resulted from inverted flypasts, flight control systems failures and turning manoeuvres. One of the more disconcerting factors in the analysis is the relatively high percentage of downline multiple rolls that ended in tragedy, there are several in the NTSB reports and in the analysis, six of the twenty-seven (22%) fatal accidents in the vertical were attributable to downline rolls.

So, what is it about a downline snap that gets away from some highly experienced display pilots? Is it poor situational awareness or just a case of excessive energy loss, bearing in mind that energy management in this manoeuvre is highly sensitive to small changes in technique? Do display pilots really let their energy budget get so close to the edge during an airshow? Do display pilots even begin to realise the extremely high rate of descent generated when pointing nearly vertically downward while conducting the roll? The question that must be asked is, how many consecutive downline rolls are available from a given height band? Is it worth 'pressing' for completing the exact number of downline rolls rather than forsaking the showline?

Unfortunately, the NTSB reports on most of these kinds of accidents are of no value to learn from, using broad descriptions at best: "Pilot failed to recover", etc. A deeper analysis of the specific cause is required, what was it that seduced the display pilot into misjudging? What is it that makes a display pilot, already flying an extremely hazardous trajectory with a fierce rate of descent, decide to do one more roll, just to get the aircraft alignment correct? Surely a safe recovery height is more important than showline? Survivors of the airshow circuit will certainly confirm that recovery altitude is a higher priority than maintaining the showline.



Graph 3. Airshow accident causal factors.

Although the analysis indicated that a higher percentage of airshow accidents occurred in the vertical than in roll, most display pilots will certainly question the validity of such findings since low-level rolls have certainly killed more pilots manoeuvring at low-level than anything else. Correct yes, but not display pilots at airshows, rather 'hotdogging' amateur pilots carrying out unauthorised low-level aerobatics. A possible reason for these surprising statistics is that display pilots are very well aware of the hazards of low level rolls

and place paramount importance in making sure that in terms of technique, their performance is flawless, or almost.
Low-level rolls are not something a pilot just decides to do, the pilot must practice the roll at high altitude until it can be executed completely without ‘dishing out’; then more work on perfecting the roll to guarantee a minimum of 100% success rate. The display pilot’s regimen must be a zero error tolerance in roll. Out of a series of ten rolls at altitude, any error at all in ‘dish’ should be an automatic reset to begin the entire series again. Ten with no dish is acceptable.
The problem is that the ‘dishing out’ is caused by not using enough rudder and forward stick during the beginning of the last half of the roll, which is the killer for the amateur doing a roll to impress friends over the field. The aircraft’s nose leaves the point above the horizon where the pilot has put it to execute the roll and starts a wide descending arc, being pulled down both by adverse yaw and by the lack of positive pitch control necessary to keep the nose pegged. This control use requires both forward stick in the corner and top rudder combined - with little airspace below the aircraft, it can be a killer. The display pilot simply cannot afford to let this happen at low altitude and still survive.

An extremely important consideration is one of situation awareness. By the time the display pilot begins working an aircraft at low-level, the pilot’s situational awareness must be as natural inverted as right side up or again, the pilot won’t be in the business for very long. That said, many pilots doing low altitude aerobatic work will trim the aircraft slightly nose low and particularly in formation aerobatic flying, this technique is even more relevant for two reasons. First, a nose low trim becomes a nose high trim when inverted and if something suddenly goes wrong while inverted and the display pilot’s attention is distracted for an instant, the nose trim may provide a safety buffer. The second reason is to keep positive pressure on the stick and avoid any neutral null in pitch forces which comes in real handy when flying a tight formation. It keeps everybody’s hand tight, and ‘tunes’ each aircraft in the formation closer to the hand/eye reactive link of each pilot.
“There is no substitute for practice in the low altitude aerobatic business. If you make a mistake, the penalty box is your own coffin. There are many professions in this world where a specific action equates to complete and total commitment. Working an aircraft acrobatically at low altitude is one of those professions - there is zero margin for error. The name of the game is simply that you don’t make errors....EVER!!! (Dudley Henriques International Fighter Pilots Fellowship)
Within the sample, a total of twenty-four Loss-of-Control accidents contributed to approximately 20% of the airshow accidents. The relatively high percentage of accidents of this type highlights the requirement for above average handling and flying skills required by the pilot, especially critical in the realm of display flying. Loss of control accidents typically included, amongst others, the Russian Tu-144 steep pitch-up which consequently led to loss of control and catastrophic structural failure at the 1973 Paris Air Show, the entry into a spin from a wingover by the De Havilland Mosquito at an airshow at Barton, UK in 1996 and the departure of the P-63 Kingcobra at Biggin Hill Air Fair in 2001. Also included under loss of control are the two Hawker Sea Fury accidents, the first on the ground during the landing roll-out where the pilot was killed when the aircraft flipped onto its back at the EAA Sun ‘n Fun 1996 and the second, the loss of control from a climbing turn at Sarnia, Canada in 2001. Surprisingly, the cause of the US Navy’s QF-4S that crashed at the Pt Mugu in April 2002 during the run-in to break for landing was assigned to loss-of-control arising from pilot mishandling.

Considering that several aircraft flying only a few feet apart at high speeds and high angular rates, it is not surprising that mid-air collisions typically account for 25% of airshow accidents. Mid-Air Collisions in the context of airshows are unique to formation aerobatics, synchronised pairs displays and pylon racing, occurring principally between members of formation aerobatics teams or the racing aircraft. In the sample, seventeen formation aerobatics mid-air collisions occurred, eight collisions occurred between synchro-pairs and three collisions occurred during Pylon Racing. Not only do collisions occur in flight, but there are of course, also cases of individual members of formations colliding while on the ground. The unusual ground collision accident in 1999 at the EAA AirVenture in the USA in which the leader of a two-ship Bearcat formation collided with the Lead aircraft of the Corsair formation on the runway – the Corsair formation had aborted a take-off ahead when the Bearcat formation suddenly commenced the takeoff run. The primary contribution to this ground collision was poor communications.

Formation aerobatics most probably represents the pinnacle of low-level display flying hazards, not only does the close proximity of the ground present a hazard, but also the extremely close proximity of the other aircraft in the formation adds significantly to pilot workload and the requirement for situational awareness. Formation aerobatics requires extremely good reactions, anticipation and fine motor skills from all the pilots in the formation. In 1982, all four members of the USAF *Thunderbirds* aerobatic team were killed when the four T-38 Talons crashed in the Nevada desert from a line-abreast loop. The first report concluded with 'pilot error' but having been 'thrown back' to the investigators, subsequently concluded that the formation leader's control stick jammed as they came down out of a loop. The second report, however, raised even more questions that were never adequately answered.

In any mechanical system, there will always be a certain failure rate, the mean-time-between-failure (MTBF). MACHINE's contribution to airshow accidents, specifically mechanical, was only 17% (twenty failures) consisting of eleven (55%) engine failures, seven structural failures (35%) and two (10%) flight control system failures. The overall contribution of 17% to airshow accidents is considered realistic considering the rigorous environment and the stresses and strains the engine and airframe are subjected to during low-level aerobatics – this, in spite of the significant numbers of vintage and ex-military aircraft on the airshow circuit worldwide.

The spread of engine failures was distributed in the ratio 5:7 between current operational aircraft types at the time of accident and ex-stock or vintage aircraft. Some of the current operational types at the time of the accidents included the P.1127 prototype's uncommanded nozzle operation at Paris Airshow (1963), the Impala engine fire at Stellenbosch Airshow (1988), the MiG-29 compressor stall, at Paris Airshow (1989) and the Harrier engine failure at Lowestoft (2002). The ex-stock or vintage aircraft engine failures included the only airworthy Me-109G-6 from Duxford (1997), two WWII vintage Spitfires, one privately owned (2001) and one belonging to the SAAF Museum (2000), the only airworthy B-26 Marauder (1995), a privately owned Hawker Hunter (1998), a SAAF Museum Harvard T6-G (2002) and a privately owned F-4U Corsair (2002). This is particularly interesting since in many aviation circles, vintage aircraft are regarded as higher risk due to their age, but statistics indicate that there is essentially no significant difference.

In terms of the definition applied, mechanical failures addressed not only engine, but also structural failure. As can be expected from the wide spectrum of positive

and negative 'g' loadings experienced during display flying, six (5%) structural failures contributed to airshow accidents. Structural failure contributed 29% to MACHINE and often resulted in some of the most spectacular crashes. John Derry's DH-110 in-flight structural break-up at Farnborough 1952, the South African Air Force's Silver Falcons formation aerobatic team singleton's wing separation in 1993 and the F-117As in-flight catastrophic wing separation at Baltimore USA in 1997, are cases in point. The in-flight break-up of the Chinook carrying forty-one parachutists in Mannheim 1982, the Pitts Special wing fold-up in Pennsylvania in 1996 and the in-flight break-up of the privately owned Fouga Magister at Deke Slayton, Winsconsin in 2001, making up the other contributions. Once again there was no statistical evidence to substantiate the suggestion that vintage aircraft are more likely to experience structural failure, despite their age. On the contrary, four of the cited examples were currently operational aircraft at the time of the accident while three were ex-Service or vintage aircraft types.
Flight Control System (FCS) failures are a relatively new phenomenon and can be expected to increase in the future as more aircraft are fitted with modern fly-by-wire systems. The introduction of fly-by-wire systems to commercial and military fighters since the 1970s has seen at least two accidents that can be indirectly attributed to such failures. The Air France Airbus 320 accident at Habsheim-Mulhouse in 1988 and the SAAB Gripen FCS induced accident in Stockholm in 1993, were recorded as the first two airshow accidents by fly-by-wire aircraft. It is however, debatable whether or not to consider the A320 as an FCS failure. Despite the aircrew's vehement counter-arguments, the official accident investigation ruled 'pilot error' in that the aircrew did not use the flight control system optimally. The ongoing argument about irregularities within the evidence produced at the inquiry and the post-accident modifications introduced to the A320 fleet, make it difficult to categorise this particular accident. In the final analysis though, it would not be incorrect to at least partly assign the FCS and aircraft systems as an indirect cause of the accident.
Still under the heading of MAN, the ever-present threat of basic flying mistakes remains a constant hazard to the display pilot; the adrenalin release of 'doing the job' safely can often lead to a form of tranquillity. A period of intense concentration followed by the sudden release of tension in completing a safe and successful display can lead to a loss of focus on the part of the display pilot. The bottom line is that the display, as in all categories of aviation pursuit, is never over until the paper work is 'signed-off' and the tendency for the pilot to relax and let his guard down before the flight is over, could result in mistakes such as a wheels-up landing. The 3% contribution by wheels-up landing incidents remains unacceptably high, especially considering that display flying is usually legislated to be flown by experienced pilots. That said, every pilot, no matter how experienced, realises the fickleness of the human and is always aware of the ease with which a wheels-up approach can be made.
Lastly, there is the element of MEDIUM, more particularly, the environment. In aviation, Medium will always contribute a certain percentage to accident causal factors, typically in the form of birdstrikes, wake turbulence and weather related elements such as density altitude, cloud base and visibility to list just a few. In the sample analysis, however, Medium's direct contribution to display accidents is surprisingly low at only 4%, constituted by 3% weather related and 1% birdstrikes (Chart 4). However, this does not reveal the true picture.

Weather contributed directly to at least three and indirectly to at least eight airshow accidents, accidents in which pilots were deceived into 'pressing', trying to squeeze their displays in below the cloud base under conditions in which the airshow could have, or should have, in most cases, been cancelled. The B-58 Hustler barrel-roll under a low cloud ceiling at Paris Airshow 1961, the A-10 Thunderbolt attempt to squeeze the loop in below the low cloud ceiling, also at Paris Airshow, but in 1977 and the synchro-pair of MiG-29s at RIAT 1993 that collided on exit from 'light' clouds while carrying out the 'lost wingman' procedure, serve as prime examples as to the hazards of conducting aerobatics at low-level with cloud present.

Strong crosswinds forced display pilots to cross the crowd line or overfly prohibited overflight areas which required the pilots to take aggressive handling action to avoid the wrath of the safety directors. Density altitude caused pilots to miss the 'energy gates', orographic turbulence contributed to formation team members colliding with each other and wake turbulence caused the uncommanded departure of a trailing formation team member.

Indirectly, weather could have contributed to at least five airshow accidents. The very high density altitude prevailing at Lanseria, Johannesburg (1977) contributed to poor energy management in the crashed loop of the Britten Norman Trislander. The B-52 loss of control in a very steep turn while trying to remain within the display arena and avoid prohibited areas was partially attributable to very strong surface winds at Washington State in 1994. The Royal Jordanian Air Force singleton aerobatic display at the 'Flanders Fly-In' in Belgium in 1997 was flown in such rain and strong winds that many of the remaining spectators took shelter in a First Aid tent, not comprehending the impact of the strong crosswinds on the pilot's ability to maintain the showline. The crash of the SAAF Museum's Piston Provost from a 'stall-turn' due to a low cloud base at AFB Swartkops in 1998 and the uncommanded departure of the Vampire trailing in the wake of the Sea-Vixen at the Biggin Hill 2001, emphasise the insidious effects of weather as indirect contributions to airshow accidents.

Considering that demonstration flying is essentially a VFR exercise, the display pilot's persistence and logic in flying displays at airshows in adverse weather conditions, is questionable. The existence of a practiced 'bad-weather' sequence in any display repertoire is essential to eliminate such accident categories, the price for non-compliance can prove fatal for not only the pilot, but also the spectators. The relatively low percentage contribution of 3% due to weather is however, considered excessive since it is theoretically possible of being reduced to zero, but that would require fine judgement and fortitude by the pilots and airshow organisers to take the 'unpopular decision' and recognise that conditions have regressed beyond the bad weather sequence criteria and either postpone or cancel the flying display.

Analysis of Airshow Accidents by Aircraft Category

The value of analysing airshow accidents by aircraft type is moot but for the purpose of comprehensiveness, it is insightful to consider airshow accidents by aircraft type. What is clear that there is no aircraft category that is spared the fate of an accident at an airshow – the total spectrum of aircraft that have demonstrated at airshows in the past have been involved in accidents in one way or the other – from the frontline fighter to ultralight. By the inherent nature of low-level display flying, there is a natural distribution of airshow accident aircraft categories. There is no doubt that spectators attend airshows to watch the dynamic manoeuvring of the different aircraft types and nearly by default, the more manoeuvrable aircraft types of aircraft performing at airshows, such as fighters, by far exceeds that of large transport aircraft types.

It is thus not surprising that the greatest number of aircraft crashes at airshows is made up of fighters at 29% and jet trainers at 23% which is not unexpected considering the high frequency of appearance and the number of fighters and jet trainers flying at airshows. (Graph 4 and Chart 5) Most importantly of course, the range of manoeuvres performed by fighters are more dynamic than the less agile aircraft and in this case, the dynamics of manoeuvring must be considered – helicopters, bombers and transport aircraft, by the nature of their intended mission and manoeuvrability, are not subjected to the extremes of handling and agility required from fighters. In fact, in the case of the less manoeuvrable aircraft, there is no significant rolling or looping manoeuvres reducing the probability of pilot errors in anticipation and judgement errors significantly. The less manoeuvrable aircraft types such as helicopter and transport types make up only fourteen (12%) of the 118 airshow crash types.

What is also interesting to note, is that from the sample of airshow accidents, vintage aircraft accounted for a total of twenty-seven (22%) airshow accidents of which 19% were attributable to vintage propeller, and 3% to vintage jet aircraft. In all likelihood, this 27:91 ratio of vintage aircraft to current operational type accidents most probably closely reflects the frequency of participation of vintage to current aircraft types.

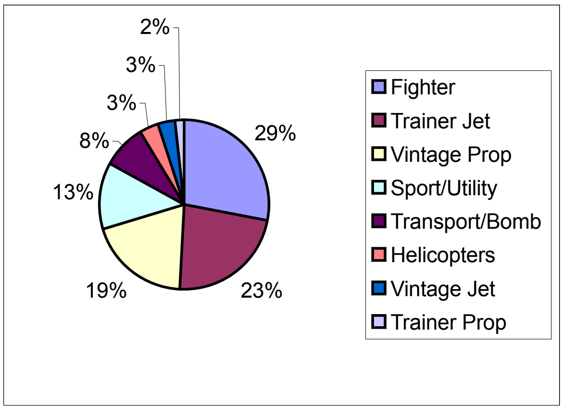
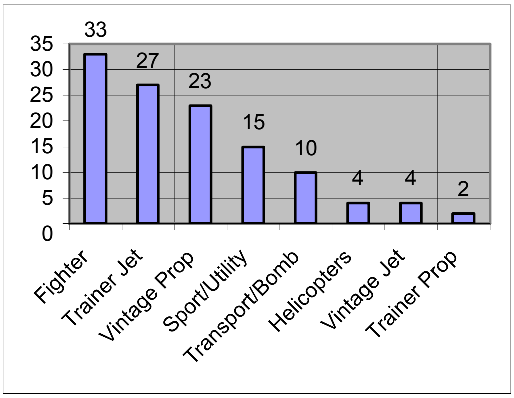


Chart 5. Percentile breakdown of airshow accidents by aircraft category.

The bottom line is that not all pilots are 'good sticks'; they may fly safely and accurately during their 'daytime job', but it takes a different type of pilot and attitude to display an aircraft at low-level. Conversely, some exceptional display pilots would possibly not survive too long in the more conventional type of flying. Certainly one of the most significant observations emanating from the analysis it that is that the pilots were all generally highly experienced, professional aviators with flying experience ranging from 3,000 to 24,000 flying hours and in several cases, more than twenty-years flying in the airshow circuit. In most cases, the accident investigation reports concluded that the pilots had erred in some way or the other. The important point to be made here is that where 'pilot error' had been identified, none of the errors were committed intentionally. What must be asked is what made the pilot respond in the manner that caused the particular accident? Why was that particular course of action pursued? What was it that drove the pilot to think that his incorrect chosen course of action would be successful? What distractions in the cockpit made the pilot select the incorrect course of action? Did the pilot experience physiological problems, were the pilot's sensors overloaded with peripheral cues and rate information, or did he just decide to 'take a chance', thinking that it would be alright? Was it an educated decision or was it just taking a chance?

We will never know the answers to these questions. Accident investigation boards make conclusions based on a given set of accident evidence – they are never privy to those vital cues, information or terrors that the pilot faced at the time of decision making, in most cases, they can never know just exactly what happened in the cockpit. The bottom line is that pilot error in most cases, has a mitigating factor that the accident investigation board do not necessarily discover or consider during the investigation. Not that this stops the Accident Board from making the standard 'clique finding' of "pilot error".

Based on the legacy airshow accidents then, airshow organisers and aviation authorities world wide, both military and civil, have had no other alternative but to introduce and impose regulations governing the safety of the spectators and public firstly, and the pilots secondly. Airshow accidents are not a new phenomenon, the statistical evidence presented in this chapter bears witness to the vast number of accidents that have occurred in the past. Statistically, the number of airshow accidents annually at airshows worldwide, is increasing, but on the good news side, the number of spectators and members of the public that have been killed or injured in Western countries has not shown any increase, which implies that the regulations imposed are in most cases, successful. Following the Su-27 tragedy at Lviv in the Ukraine in which 86 spectators were killed and 156 injured, it is clear that standardisation of safety regulations throughout the world is essential if spectator safety is to be maximised. The weakest part of the safety chain however, remains the pilot and it is only through trying to iron out the weaknesses of each individual display pilot that airshow safety can be enhanced.



Graph 4. Airshow accidents by aircraft category.

These statistics leave one in no doubt as to the fallibility and weakness of Man in the low-level demonstration environment. Armed with these facts, it is essential for Man to focus on his weaknesses and develop counters for them to improve survivability indices. This once again emphasises the fact that the display arena is a hostile environment. Flying high momentum aircraft in three dimensions very close to the ground at extremely high closing speeds and high angular rates, which when coupled with the human's inability to accurately measure closure rates, makes for a high risk of misjudgement by a pilot.

What can be gleaned from the foregoing statistics and analysis is that the range of contributory causes to airshow accidents is extensive. From insidious elements of weather and mechanical or structural failure, to totally unprofessional flying and blatant disregard for safety regulations. It is evident that there is no single, major factor that leads to an airshow accident. The display arena is a hostile environment. Controlling an aircraft in three dimensions very close to the ground at high closing speeds and high angular rates, creates a high pilot workload and a lot of adrenalin. When coupled with the human's inability to accurately assess closure rates, it makes for a high risk of judgement error by the pilot. In display flying, the margin for error is zero. It is not necessarily display pilot skill that is the problem, but rather pilot judgement.

CHAPTER 4

ACCIDENT CASE STUDIES

Former world champion acro-pilot, Lithuanian Jurgis Kairys flies his Su-26 under a bridge in Vilnius. *(Jurgis Kairys)*

"Truly superior pilots are those who use their superior judgment to avoid those situations where they might have to use their superior skills." (Anon)

INTRODUCTION

Accident Investigation Boards are an essential component of any aviation authority, military or civilian, and exist to investigate any and all accidents with the primary aim of determining the cause and introducing procedures to prevent the same mistakes being made again. In most countries, the Air Accidents Investigation Branch (AAIB) is a part of the specific country's Department for Transport and is responsible for the investigation of civil aircraft accidents and serious incidents within the that particular country. The Chief Inspector of Air Accidents usually reports directly to the Secretary of State for Transport. Within military circles, accident investigation is usually the remit of the specific air force's Directorate of Aviation Safety or similar department.

The fundamental purpose of investigating accidents is to determine the circumstances and causes of the accident with a view to the preservation of life and the avoidance of accidents in the future - not to apportion blame or liability which is a legal prerogative outside the remit of an accident investigation. In considering random accident case studies, the UK's Air Accident Investigation Board (AAIB) and National Transportation Safety Board (NTSB) accident investigation reports are reproduced nearly verbatim with only slight changes in grammatical tenses with commentary by the author relating the accident case to the dynamics and realities of display flying. Accident investigations are supposed to be unemotional and objective reports in which conclusions must be supported by fact, not hypothesis or opinion. Such reports are of a technical nature and the written style is usually abrupt and not in the novel form. Unfortunately, the unavailability of hard accident causal evidence and facts often makes it difficult for investigation teams to reach conclusive findings and as such, a comprehensive technical analysis of each accident leads to objective conclusions and recommendations.

In an overview of selected fatal accidents, the devastating Su-27 loss-of-control crash in the Ukraine in 2002 is considered. The AAIB's Bell P-63 Kingcobra loss-of-control crash at Biggin Hill 2001, the NTSB's Canadair Sabre F-86E flight-into-terrain crash in 1993 at El Toro Marine Corps Air Station, California and the AAIB's flight-into-terrain of the P-38 Lightning at Duxford's 'Flying Legends' Air Display in 1996 provide a broad-brush analysis of accidents representing a wide spectrum of airshow accidents. The non-fatal crash of the South African Air Force Museum's only airworthy Spitfire describes the inner thought processes of a pilot in a survivable accident while an analysis of the USAF *Thunderbirds* four-ship formation fatal accident in the Nevada Desert in 1982, serves to highlight some of the real world questions that are not always considered by accident investigation boards for whatever reason.

The specific examples serve to verify the vulnerability of pilots to the hazards of low-level display flying. There is no differentiation in category of pilots or aircraft, military, civilian, ex-military all are equally vulnerable to the hazards of the airshow environment. High time pilots with thousands of hours, modern fighters to vintage propeller aircraft, there is no discrimination.

It is always easy to be clever after an accident; "hindsight is an exact science" or so the quotation goes. Questions that however remain unanswered are: "How in today's world can an air force task a frontline fighter like the Su-27 to perform at an airshow without adequate practice and knowledge of the display arena? Even worse, instruct the pilot to fly overhead the crowd for maximum effect? Why a highly experienced display pilot flying the Kingcobra applied full up elevator and full right rudder while inverted at the top of a low-level loop? Why such poor communication without inadequate back up existed at Biggin Hill for the Flying Control Committee to stop the show routine after the aircraft entered the first incipient spin? What would make a highly experienced display pilot continue a display after entering an incipient spin and then immediately re-enter the next vertical manoeuvre in the sequence with an excessively low airspeed? Is it overconfidence, ego, unpracticed, situational awareness?

How could an experienced display pilot make the decision to perform a low-level display in a Sabre without a well-practiced sequence? What would make one of the world's most experienced vintage aircraft display pilots conduct two consecutive aileron rolls in a P-38 Lightning at low level even though the normal procedure was to only conduct one roll? The relatively poor roll rate and the requirement to positively keep the nose above the horizon are well-documented techniques for vintage aircraft aerodynamics? There are so many unanswered questions resulting from fatal accidents.

Could it be that airshow pilots have inadequate flying hours on specific types and insufficient continuation training to reduce the risks of handling and anticipation errors during the low-level display? Could it be that pilots do not plan their displays considering the worst-case scenario of failure? Does the art of pre-planning even exist in some cases? Could it be that some display pilots do not fully consider and plan for each specific manoeuvre of their routine and then rather make in-flight energy management decisions on an 'ad hoc' basis? In considering the fatal accidents, the question of supervision must be continually raised. Are display pilots adequately focussed on the task at hand, are their minds on the task at hand or are they busy with 'other distracting issues, domestic or show organizing?' Can or should display co-ordinators be allowed to fly at the airshows? Is age a handicap to safe display flying? These are all 'real-world' questions that must be answered if display flying is to achieve lower accident rates.

The dynamic environment requires that pilots are not only in current practice on the particular aircraft type, but should also be at peak physical condition. High angular acceleration rates and high G-forces place a high fatigue load on the human body and it is one of the reasons that air force fighter pilots are drawn from the younger ranks. Is it possible that age makes display pilots more susceptible to airshow accidents? Is there any scientific evidence militating against 65 to 80-year old pilots displaying aircraft at airshows?

With age, the ability of the display pilot to continuously absorb the highly dynamic manoeuvres, decreases, just as it does for professional sportsmen. But as they get older, they also get wiser and eventually understand the value of peak physical fitness that youth provides. That said, the ironic side is that experience only comes with age, display pilots get clever in knowing 'when' and 'how much' to pull, 'when' and 'how much' to roll, to still create the best spectacle – this is not something that an inexperienced youngster generally can do, it is a 'feel' that comes from experience. There have been airshow accidents in which the possible causes were listed as possible medical causes, but the question of pilot incapacitation is often one of the variables in airshow accident investigations difficult to confirm.

THE WORLD'S WORST AIRSHOW DISASTER

Any dissertation on display flying would not be complete without at least discussing the tragic events surrounding the world's most disastrous airshow accident in history, the Ukraine Air Force's Su-27 that ploughed into the spectators at Lviv, Ukraine on 27 July 2002. Just when airshows worldwide appeared to have achieved a standard in which the safety of spectators was no longer jeopardised by display line incursions, a Ukraine Air Force Su-27 crashed into a spectator enclosure at an airshow at Skniliv Airfield and exploded in a fireball killing 86 people (including 27 children) and injuring more than 156. The accident occurred at the airshow to mark the 60th anniversary of the 14th Air Division of Ukraine's Air Force. The Su-27 had amazed audiences at its first appearances at Western airshows in the 1990s with aerobatic manoeuvres previously unknown and unheard of for a twin-engined jet aircraft of its size.

The actual impact of this accident on airshows worldwide had far reaching implications for the way aircraft are displayed. Vociferous comment by display and ex-display, military and civilian pilots worldwide was forthcoming, in particular, the UK and the USA. Farnborough Airshow 2002 was in full swing at that time and the world's attention was focussed on the safety regulations in force at Farnborough. Several commentators, attempting to protect the airshow circuit from the media and also looking after public interest and attendance figures, claimed that such an accident could not happen at Farnborough or even in the UK.

The supposition put forward was that the strict regulations in force would negate the probability of such an occurrence – a shortsighted prediction if ever there was one. The fact of the matter is that any air vehicle, even with moderate airspeed, could very easily transgress the safety buffer between showline and spectator enclosure. An aircraft departure from loss of control or catastrophic structural failure for whatever other reason, could change the directed inertia and traverse the safety buffer zone of 450 metres in a very short space of time, certainly less than five seconds, definitely not enough time for the pilot to regain control and steer the aircraft away in a safe direction or for the spectators to evacuate the enclosure. The Su-27 airshow crash serves to confirm this statement of fact.

Approximately two minutes into the display routine, and from analysis of video footage, the aircraft was in a tight left hand, level steep turn when for some inexplicable reason, the aircraft suddenly rolled over through another approximately 110º into a steep, nose-low, inverted position. The pilot instinctively proceeded to pullout from the ensuing dive from which it failed to recover due to insufficient height. It is highly unlikely that this manoeuvre was intentional; no pilot in his right mind would attempt this ‘half-roll pull through; from such a low altitude. During the uncommanded roll, the aircraft became displaced from the showline heading directly at the spectator enclosure.

During the uncommanded roll, the aircraft became displaced from the showline heading directly at the spectator enclosure. (Associated Press)

From the video analysis it appeared as if the left engine had failed and the aircraft yawed and rolled left. The ailerons were clearly full right stick and the rudders were full over to the right the whole way down to the ground, and it looked like there was no roll recovery at all. Fortunately for the crew, they initially hit the ground at a small enough bank angle for the impact to tip the aircraft to an attitude approximating straight and level.

According to a Russian flight test engineer that had previously worked on the Su-27 development programme, when the Su-27 loses an engine at high power settings, the yaw and roll is uncontrollable - the standard recovery technique if altitude permits, is to bring both throttles to idle and recover roll control in the dive, and then fly home. There is more than enough power from the remaining engine to fly home at low enough power settings so that the yaw/roll mechanism is controllable. Rather surprising considering the narrow thrust lines involved. But factoring in a left yaw/roll moment from the port engine failing with the right at engine at power, occurring simultaneously with the pilot induced left roll, could only end in catastrophe, especially at such low heights. The right control deflections were maintained prior to impact and considering the high AOA and ineffective control response against the momentum, the pilot was fighting a losing battle all the way down. If the aircraft did lose one engine, then it would have been at the absolute worst possible moment it could have happened. The left wing appeared to drag on initial ground contact which positioned the cockpit just long enough to allow an ejection that taxed even the superior Zvezda seat.

Both crew ejected between the aircraft being tilted erect after scraping the ground and the explosion in the cartwheel; one of the empty seats actually fell into the fireball. Both pilots Vladimir Toponar and

Yuri Yegrov, the co-pilot, survived the ultra-low ejection but suffered fractured vertebrae. If nothing else, it once again demonstrated the Russian Zvezda ejection seat's capabilities. The pilots ejected only after impact with the ground was the only option, an indication that they were struggling to control the aircraft and prevent the impending impact with the ground and spectator enclosures. The aircrew were correct to stop fighting the aircraft and to make the instantaneous but very late decision to eject when all was lost. Due to a slight discontinuity in the video coverage it was hard to tell, but it looked like less than two seconds between first ground impact and the cartwheel.

The considered opinion of those pilots who weighed in with comment on this, was that there was absolutely no way to point this aircraft away from the crowd, since full right rudder and aileron were already being applied with no effect to counter the yaw from the failed port engine with the right still at high power setting. The aircraft banked left to an angle of approximately 40º at first impact and was then slewed into the spectators watching in horror as the aircraft ploughed across the airfield before bursting into flames. Dazed and bloodied survivors of the tragedy stared in shock and horror at bodies of the victims strewn over the ground.

The intention of a pilot trying to avoid crashes into populated areas is honourable, but it must be understood that there are circumstances when a high performance aircraft like the Su-27 can become nothing more aerodynamic than a rock. Such was the case in this accident. The pilot never had a chance to avoid the crowd once that left roll had been initiated. Suffering a port engine shutdown at the worst possible moment in the manoeuvre as he was initiating a left roll with lateral stick in the same direction that the failed port engine produced a high yaw moment in series, resulted in a twisted roll with an extremely high angle of attack recovery that denied further effective control input. His only chance to avoid the crowd was when he was originally positioning his aircraft for that roll, which on his own admission, was overhead the crowd as instructed by his commander.

The final analysis of this horrible tragedy involved isolating the exact point in space the aircraft occupied, as well as it's heading in relation to the crowd at the point when the aircraft encountered the problem that brought it down. As for the ejection itself, there was absolutely no question in the minds of other experienced pilots who saw this happen, that the aircraft was completely out of control through the roll and on the edge of an accelerated departure due to excessive angle of attack all the way down through initial impact.

The photographs were rushed to the media and published worldwide which had a pronounced shock-effect on a world in which television coverage of carnage has become common viewing. The burning wreckage of a twenty-five ton aircraft ploughing into the spectators, next photograph, dead, mangled bodies scattered around. The type of photographs that could influence even the most diehard airshow supporter to supporting initiatives to ban airshows – it was those kind of photographs. What a mess!

Experts unanimously blamed the organisers of the airshow for the disaster. Former Ukrainian air force general Vadim Grechaninov, told Interfax that the pilots of the Sukhoi were unable to avoid ploughing into onlookers because of improper safety measures on the ground, and because the aircraft was flying too low. Another Ukrainian expert, former fighter pilot Colonel Alexei Melnik, agreed, saying that the air force had flouted the rules stipulating that demonstration flights must be performed at an altitude not lower than 400 metres. Besides flying below show altitude, the close proximity of the spectators to the show line also contributed to the high numbers of fatalities.

Fingers of blame were immediately pointed at the Ukraine, of course. Some were saying that the pilots had modified the routine to demonstrate an unapproved even, some said, 'unpractised' manoeuvre; others blamed the air force for not calling the demonstration off when it became apparent the routine wasn't going by the book, and/or for ordering flight over the spectators, presumably for maximum crowd thrill; still others said the pilots should have recovered in a different direction and a few even blamed the aircraft.

As word of the disaster spread throughout the world, and in a flurry of rash actions, enraged Ukrainian President Leonid Kuchma immediately dismissed the Air Force Commander, General Col. Volodymyr Strelnikov and Commander Serhiy Onyshenko who were under investigation for criminal negligence as well. The Defence Minister also offered his resignation but

Kuchma refused to accept it. Meanwhile, a military court in Lviv ordered the flight's ground-control leader, Yuriy Yatsuk, jailed on charges of criminal negligence. Judge Oleksandr Yaremenko said that Yatsuk should not even have controlled the exercise. "He was not experienced enough to lead Su-27s flying at low altitude in manoeuvres requiring the highest level of piloting," Interfax quoted the judge as saying.

Speaking at the site of the tragedy, a shocked Kuchma who cut short his vacation in the Crimea to fly to the crash site, said that the air force should concentrate on their military duties rather than performing for crowds. "In my opinion we need to stop these kind of air performances. People should do their military business and should train, not take part in airshows," Kuchma told local television stations. We don't know anything absolutely except that the pilots were the most experienced, of the highest class," Kuchma said in comments shown on state television.

Struggling to speak, the veteran leader said the worst thing about the crash was that "innocent people died." Kuchma also ordered the secretary of the Defence and Security Council, Yevhen Marchuk, to lead a government commission to investigate the case and announced a ban on military airshows in Ukraine while vowing to pursue those responsible. "The culprits should be punished, there is no doubt," he said.

Residents in this western Ukrainian city began two days of official mourning Sunday after a fighter jet crash. Music and entertainment programs were curtailed as residents attended church services to pray for the victims. Hundreds of anxious relatives waited outside the Lviv morgue for officials to identify the victims, whose bodies were being held in refrigerated trucks outside pending identification. "These are sad statistics," Marchuk said. He said the remains of twenty-five victims had been identified, but the badly mutilated condition of many other victims was making the identification process difficult. "The highest priority is to identify these people," he said.

Mykhailo Kurochka, deputy head of Lviv's police service, said officials had begun to call relatives of victims to start the identification procedure. "One-by-one, they will be taken to identify bodies, which will then be prepared for funerals", he said. Svetlana Atamaniuk, whose daughter and granddaughters were killed, waited with the others for official confirmation of their deaths. She said that she was at her home across from the airfield when she heard the plane go down. "It was ripping the air," she said. "My only daughter, her husband and their two daughters are lying in there," she said late Saturday night, waiting outside the morgue for information. "I can't get in, I will be here until the morning," she said.

Many of the bodies were in terrible condition, complicating the identification process.

Bohdan Hupalo, 18, said he was posing for a picture when the plane came down. He dove to the ground and saw the jet race over him, missing by only a few yards. "There weren't any survivors among those who fell down late - they were cut down like grass," he said. When Hupalo opened his eyes, he said he was surrounded by human remains. "I will never forget this tragedy," he said from his hospital bed, where he was being treated for an injured back. After the crash, parents frantically searched for missing children and used the public address system to call out their names. One group of children with cuts on their faces and arms sat stunned on the ground. Severed body parts littered the tarmac at the air base. One woman was seen clutching the lifeless body of a child in front of a jet on display; another man was covered in blood while he examined the stump left of his right hand. More than $1.9 million was set aside from the federal budget in an initial fund for funerals and first aid for victims, Kuchma said. (Interfax News Agency)

Comment by a veteran airshow performer: "When he completed the half roll, he yanked a yard of stick and pulled the aircraft in deep stall, effectively on the ragged edge of an accelerated departure all the way down. It was hard to tell from the video angle just where he was in the manoeuvre set-up when the screw-up occurred, and I hate to speculate without seeing the set-up sequence, but he very well might have been bitten by something I feel has killed many pilots working an airplane that low."

"I considered it a safety one issue in any and all low routines I ever did, and watched for it VERY carefully. It occurs when you are doing a manoeuvre series in fairly rapid succession. What happens is that somewhere in the sequence, you find yourself just a hair off of where you actually should be for the next manoeuvre. It could be in roll, but more often than not, it's a pitch error. You make an instant decision and decide the error isn't enough to break the sequence, and initiate

the manoeuvre anyway, fully aware of the slight error and thinking you will correct the error AS THE MANEUVER PROGRESSES! This can kill you...especially in roll!" "Who knows if this is what caught him, but from the video analysis, it is most probable that something happened to blow his exit heading as well as his altitude problem. I feel for this poor guy! I just hope he wasn't breaking any regulations when this happened. It's going to bad enough for him without that!"
The official accident investigation report concluded that that the cause was 'pilot error'. Chief investigator Yevhen Marchuk, said that he blamed the pilots for the crash, saying they broke from their flight plan and performed difficult manoeuvres which they had not done before. He added that operational issues, organisational problems and a lack of safety measures had contributed to make it the world's worst airshow disaster. He elaborated by implicating the pilots' flight commanders and the airshow's organizers, who he said did not conduct a rehearsal of the event. "The pilots were not properly instructed on their task and the two pilots had only trained for three days before the show but didn't see where they would perform until they arrived in the western city of Lviv on the day of the show". He also said that commanders failed to call off the performance after the pilots deviated from the flight plan on their first pass, flying too close to the public. The question it raises in this case is of course: "why would the commanders call it off if they had instructed the pilot to fly overhead the spectators for increased effect in the first place?"

According to witnesses, the jet flew directly over the crowd of about 10,000 people. In many countries, crowd exclusion zones are enforced at airshows and pilots are barred from carrying out manoeuvres below a certain height. Mr Marchuk said there was no proper co-ordination among the bodies taking part in the show. The two pilots had been serving in different wings, the flight controller came from another base and the jet was supplied by yet another unit. Mr Marchuk also accused the ground services of not taking adequate measures to ensure the safety of spectators. As in several high profile aircraft accidents, the conspiracy theorists were not slow in getting into the act. The theory was mooted in the media soon after the accident was that the aircraft was brought down by a mysterious cylindrical object, but this was rejected by the commission.

Although technical failure was rejected as a cause by the president of the Accident Investigation team, from the video footage it certainly looked like the aircraft experienced a compressor stall or complete failure port side just as he had initiated a tight left turn which torqued the aircraft around nose down. This was followed by a strong positive pitch input during recovery that over-rotated the aircraft right through critical alpha and deep into drag rise putting the aircraft right on the razor edge of a departure. It was a 'done deal' all the way in - it's a miracle they got out at all. If the wingtip hadn't grazed the ground just before final impact, rotating the lift vector back into the seat envelope for just the instant they hit the handles, they wouldn't have made it out at all.

In an interview with the Ukrainian news agency and reported by the British publication The Guardian, Vladimir Toponar, the pilot of the Su-27 'Flanker' didn't agree that he and fellow pilot Yuri Yegrov should be held responsible for the accident. The pilot said, "At the decisive moment, the plane became uncontrollable, it was completely unexpected. I fought the plane up to the last second to spare as many people as possible and only thanks to Yegrov did we save our own lives." Contrary to the statements released by the Accident Investigation Board, the pilot's description and perception of what happened seemed to collate with the video footage. The same statements were repeated by Volodymyr Toponar to the UNIAN news agency carried on Ukrainian STB television which confirmed that published by the Guardian blaming technical problems and a faulty flight plan for the crash.

It was the first public comment from either of the pilots after doctors had pronounced the pilots fit enough to answer investigators' questions. Toponar's comments came after the chief investigator accused the pilots of ignoring their flight plan and attempting difficult, untested manoeuvres that caused the plane to nick the ground, slice through a parked plane and cartwheel into the crowd. "The pilots failed to follow the flight plan and performed four difficult manoeuvres that they had not done before," Yevhen Marchuk, the chief investigator of the accident, said.

The decision whether to prosecute the pilots would only be made after they had fully recovered, a spokesperson from the prosecutor's office said. Toponar was released from hospital after a month while Yegrov needed two months to recuperate. Toponar said that he was following orders in flying over the crowds. "The flight shouldn't have been performed over people, but the order was

to fly where people were", Toponar told STB television. All in all, not only a sad indictment of airshow safety regulation application and supervision in the Ukraine, but also total disregard of the implications of an accident on spectator safety, a shame really!
Releasing the preliminary results of its investigations, Marchuk's commission said that pilot error and officials' failure to prepare for, plan and execute the show safely were the main causes of the crash. Marchuk rejected pilot Volodymyr Toponar's claim that technical failures caused him to lose control of the Su-27 seconds before the crash. "All of the plane's systems worked properly until it hit the ground," he said. The commission recommended restructuring Ukraine's armed forces and speeding up military reforms. President Leonid Kuchma adopted Marchuk's proposal to increase funding of the cash-strapped armed forces and instructed his Cabinet to submit draft laws to parliament strengthening flight regulations.

By 14 August 2002, the first of what promised to be a series of lawsuits against the government, the father of a 24-year-old man killed in the accident sued the Ministries of Defense and Health and regional officials, news reports said, seeking $66,000 in damages. (AP)

The apparent reason for limiting the pilots to only three practice flights was attributable to 'budgetary constraints' and it is here that the accident began, the first domino was knocked over, setting off the rest. It is all very well for the President to dismiss the middle management, but in fact, fingers should ultimately point all the way up to the Ukraine Government. No military can operate without a proper budget that can assure that the operators of equipment are adequately trained – these are the first principles of health and safety in any professional organisation.

Even more distressing was that the Government was quick to provide additional funding to the military after the accident. After the unnecessary deaths of eighty-six people it is a sad indictment of society in general, it is easy to just say, 'typical' – people must first be killed before the urgency of a situation is realised. A very important lesson from this accident was that after the event, the pilot discovered just how few friends there are. The pilot could have refused to fly the display in the knowledge that insufficient practice and preparation had been done, but in the spirit of 'getting things done', he did not. However, when things went wrong, all peripheral support dried up and the 'action men' were left to be the 'fall guys'. It is an unfortunate fact of life that management systems always needs someone to blame, in this case, the pilots and their immediate seniors. Unfortunately accident investigations tend to be "bottom-up" not "top-down" processes. Supervision in flight safety must be "top down", it cannot function effectively "bottom-up".

Accident investigation teams, unless the exact cause can be confirmed, normally avoid speculation, understanding that if one was not in the cockpit at the time of the accident, it is difficult to reach conclusions with any certainty. In some cases, the cockpit voice recorder (CVR) of course can provide definite evidence of what transpired aboard the aircraft, carrying with it the emotions, actions and terrors facing the aircrew. A Ukrainian translated the cockpit voice recording directly to English and the English translation may not exactly replicate the English aviation terminology exactly.

On 27 July 2002, Vladimir Toponar was the pilot in command of the Su-27 and Yury Yegorov, the co-pilot. Anatoly Tretyakov was the vice-commander of the 14 th Air Division and Yury Yatsuk, the assistant controller in the display arena.

12 .40.30. Yatsuk (Ground Controller): "2000 metres, some thin broken clouds. Weather is good, visibility better than 10 kilometres".
12.40.47. Yegorov (Co-Pilot): "Look, Volodya, the weather is good".
Toponar (Pilot): "Take the controls".
Yegorov: "Taken".
12.41.09. Toponar: "Turn right".
Yegorov: "Roger".

12.41.17. Yatsuk: "31152 turn right, landing course 312, bearing 136, distance 24. Altimeter 738, descend 600".
12.41.25. Toponar: "Come out, come out of the bank, come out".

12.41.33. Toponar (to Ground Control): "Descend 600 31152".
12.41.36. Yatsuk: "Roger. Altimeter 738,0 set?".
12.41.44. Toponar: "Set".
12.41.52. Tretyakov (Ground Controller): "31152, this is Lavender (callsign)-- start". Toponar: "31152 Responding: leaving 1500".
12.41.59. Tretyakov: "Good, using altimeter 738,0 descend 600 metres inbound to the marker".
12.42.06. Toponar: "Descending 600 inbound to the marker".
12.42.11. Yatsuk: "152, radio check Lavender-base?".
Toponar: "Loud and clear".
12.42.16. Toponar: "Turn left 10".
12.42.23. Toponar: "Now come out".
12.42.38. Toponar: "That's all. Observing". Yegorov: "Yes, slow down".
12.42.41. Tretyakov: "31152 once again, make sure altimeter is set to 738,0". 12.42.50. Toponar: "738,0 set, runway in sight 600 horizon".
12.42.56. Tretyakov: "Good. What's the visual distance?"
12.43.00. Toponar: "Visually about 10 kilometres. Request descent lower".
12.43.05. Tretyakov: "Yes. 152, you're in sight, further descent approved according to mission plan".
12.43.13. Yegorov: "Vova (to Toponar, short for Vladimir), trim the plane and let's start from 300 metres. Vova, let's not, why would we go there?.." Toponar: "OK".
12.43.26. Yatsuk: "152, I'm Lavender-base: observing, you're cleared to start".
12.43.31. GPWS warning (lasts for 5,5 seconds).
12.43.33. Yegorov: "We have too much remaining, understand...?"
12.43.37. Yegorov: "6 tonnes, understand?"
12.43.43. Toponar: "Where the f... is the crowd?"
12.43.48. Yegorov: "I don't know where the f... they are"
12.43.49. Toponar: "Ah, there, I see".
Yegorov: "f...our mother...! There's none on the right!"
12.43.54. Toponar (to the ground): "Executing pilotage to the left".
Yegorov: "So, let's roll?"
12.43.58. Yatsuk: "Left, left".
12.44.14. Yegorov: "Turn it on".
12.44.34. Yegorov: "Let's go".
12.44.36. GPWS warning.
12.44.39. Yegorov: "Barrel roll".
12.44.44. Yegorov: "Enough -- angle".
12.44.51. Voice warning: "Flight 42, speed at the limit".
12.44.58. Yegorov: "Turn". Voice warning: "Flight 42, critical angle of attack, critical G-load".
12.45.01. Yatsuk: "Turn".
12.45.02. Yegorov: "F...... turn".
12.45.05. Yatsuk: "Come out".
12.45.07. Tretyakov: "Come out, add RPM".
12.45.10. Yatsuk: "Afterburners".
Voice warning: "Critical angle of attack, critical G-load".
12.45.11. Tretyakov: "Add RPM".
12.45.18. Recording stops.

Just listening to the cockpit voice recorder and studying the crash video footage provides significant insight into those last few minutes in the cockpit and also seems to contradict some of the findings of the Accident Investigation Board. Firstly, the weather was partly cloudy and fair at the time, and did not contribute to the accident. Secondly, the report ruled out technical failure and concluded that there had been no plan, that unpracticed manoeuvres were attempted and that there was no effort on the Ground Control Team to warn of the impending catastrophe or cancel the display.

Well, there certainly seemed to have been a plan. At 12.43.05, the vice commander of the 14th Air Division, Tretyakov, cleared the Su-27 down according to "mission plan," whatever that implied. If there was a technical problem, the pilots were unaware of it or did not have time to discuss the aircraft behaviour. From the time 12.44.44 it appears that the uncommanded motion of the aircraft put it on an incipient departure, both maximum angle of attack and critical g-load limits were approached. The susceptibility to departure would have been increased by excessive fuel weight which the co-pilot brought to the attention of the pilot at 12.43.33. The higher display weight would have made the aircraft all the more difficult to control especially considering that the aircraft had basically become 'a dumb flying bomb'.

The pilot flying the aircraft would have been mentally saturated trying to work out 'what the hell was happening' to the aircraft – under such conditions, there is no time to assess, it becomes purely a matter of survival and a reversion to basics trying to prevent the aircraft from impacting with the ground. For the pilot, the co-pilot and the controllers, moments of sheer terror!!

It is prudent ask: "Under the prevailing conditions, would the pilot have even realised that the port engine had failed, especially considering the narrow distance between both the engines? It is prudent to note that during the last seventy-seven seconds, the pilot made no audio input, he did not speak at all, respond or acknowledge any information provided by the co-pilot or ground controllers which is indicative that that he had his work cut-out just trying to fly the aircraft. Not surprisingly though, the co-pilot is heard continuously pattering the pilot flying the aircraft with irregular messages from not only the ground controller Yatsuk but even from Tretyakov, the vice commander of the 14th Air Division. Then there was the aircraft's continuous voice warnings being activated in the background – to say that the audio traffic for the pilot at a critical stage of flight was excessive, is an understatement and the pilot's sensory cues would have been bombarded with input and rapidly reached saturation level.

For the Accident Investigation to conclude that the Ground Controllers were negligent for not exercising firm control over the display is maybe a bit harsh. Within the first set of manoeuvres of the sequence, the aircraft departed controlled flight – leading up to the crash, the Ground Controllers were constantly pleading with the pilot to "turn", to "come out" and even to "add RPM". Not physically being in the cockpit meant that the controllers had no direct effect on the ultimate outcome – especially in the final thirty seconds when the aircraft was essentially out of control.

From the CVR at 12:44:39, Yegorov called for the barrel roll but during this manoeuvre, in fact twelve seconds after calling the barrel roll, the airspeed limit was approached, by nineteen seconds, just seven seconds later, the voice warning called "critical angle of attack" and "G-load" and at twenty-two seconds the co-pilot and ground controllers instructed the pilot to "turn". Only one second later the co-pilots' exasperation is clear in his instruction to the pilot to "f……ing turn". The Ground Controller at twenty-six seconds pleading for the pilot to pull out followed two seconds later by the Division Commander commanding the pilot to "pull out!!!" The Ground Controller plus the Division Commander in desperation even called for the pilot to select afterburner and increase RPM but whether the pilot, his mental and audio capacity saturated by information overload, was able to comprehend, is uncertain. From starting the barrel roll, thirty-nine seconds elapsed before final impact and the death of eighty-six spectators.

The comments at 12.43.43 from the pilot stating that he did not have the crowd-line visual implies that no previous site study had been completed, nor a pre-show practice conducted. Herein lies some of the most damning evidence of unprofessional conduct and an indication of a total disregard for safety, in particular, spectator safety. Flying overhead the spectators left no buffer to cater for failures of any sort and any type of mechanical failure could in all probability have contributed to the large number of spectator fatalities that actually occurred.

The crash recorder data was apparently recovered and a 3-D model of the flight path was computer simulated. All aspects of the preparation of the show and responsible personnel actions were investigated, as well as the radio communications with the ground. It was concluded that contributory causes included the flight crew not having a flight card, the flight crew was not briefed about the features of the airfield, there were no practice flights in the display arena, the show officials did not co-ordinate the participant's actions and when the aircrew violated the display arena, ground control did not warn them that the event itself was allegedly not approved by the local authorities and the requirement for the practice flights was dropped. The flight data showed that the manoeuvring took place at the altitude lower than 200 m, which was well below the airshow limit.

One can understand that no mechanical system is perfect and that failures do occur in the real world – it is the impact of such failures that must be considered not only from the pilot's perspective but also from the spectator safety perspective. Failure to do so can quite rightly be regarded as grossly unprofessional and negligent in the extreme. Considering the horrendous accident, it is possible to feel for the pilots, but considering the poor and total disregard of airshow safety exhibited by the pilot and also the air force, the decision by the Accident Investigation Board and the rash response of the President, is considered just.

Worldwide, besides sentiments of sympathy and concern for the spectators that were killed and injured, there was also concern as to what effect this accident would have on the airshow world, particularly the regulations governing display flying. The entire airshow community would be affected in some way or another before the Accident Board had deliberated. More particularly, the aircraft heading in relation to the crowd at the manoeuvre onset was critical. If the pilot initiated in violation of current regulation limits for crowd proximity and heading, the impact would be minimal. But, if the final analysis of the entry heading put the aircraft inside present regulations, and what happened to the aircraft as a result of losing the left engine at manoeuvre onset took him through that roll, twisting the aircraft out with an exit heading at the crowd, then it is difficult to predict the end result.

The FAA certainly looked at this scenario in great detail, and some regulation changes would be instituted in the United States. No matter what happened, though, it was not good for the airshow community, especially the military community. One last thought for the pilot...rummaging through the crowd.....on his way to a hangar...whatever...probably wished he were dead. What a tragedy indeed bringing back memories of *Frecce Tricolori* in Ramstein in 1988. From the results of the on-line survey question posed by CNN immediately following this accident, it becomes easy to understand the rationale behind 30% of the respondents agreeing with the statement "airshows should be totally banned?"

Air Accidents Investigation Branch

BELL P-63A-7BE KINGCOBRA: BIGGIN HILL 03 JUNE 2001

The Bell P-63A Kingcobra aircraft was being flown in an air display at Biggin Hill. The pilot displayed the aircraft successfully on the first day of the airshow but on the second day, at the top of a vertical manoeuvre, he appeared to lose control and the aircraft departed controlled flight before impacting the ground in a steep nose-down attitude.

On the second day of the airshow three American World War II fighter type aircraft were scheduled to perform a joint display. With the Kingcobra designated to be the third aircraft, the plan was for the three aircraft to fly together initially, while performing various manoeuvres. The Kingcobra would then break away and the first two aircraft would carry out a pre-planned routine together, consisting principally of low-level horizontal manoeuvres. The role of the Kingcobra was to 'fill-in' between these two aircraft with a display that included some vertical manoeuvres. This arrangement meant that unlike the first two aircraft, the Kingcobra was not flying a pre-planned sequence.

All three aircraft waited at the holding point for Runway 03 for fifteen minutes before takeoff. After take-off the aircraft held to the west of the airport for three minutes prior to commencing their display. They then ran in together and each performed a loop followed by a half Cuban eight, following which the Kingcobra broke away from the other two as planned. One minute later, after performing a flypast along the display line at a measured speed of 220 kts and having passed opposite the other two aircraft, the Kingcobra was seen to pull up into a rolling climb. At the top of this manoeuvre, with the aircraft partially inverted, the pilot appeared to lose control and the aircraft entered an incipient spin. The pilot recovered the aircraft, having lost considerable height, and then continued with his display.

Next he flew past the crowd from left to right, carried out a wingover to the left and returned past the crowd from right to left at 190 to 195 kts. The aircraft then went out of view for some twenty seconds, in which time it turned to the right through some 220° before running in directly towards the crowd and pulling up into the first half of a loop. At the top of this manoeuvre, in the inverted position, full nose-up elevator was maintained and a substantial amount of right rudder was applied. The aircraft yawed to the right and then departed into an upright incipient spin. The nose dropped steeply, full nose-up elevator was maintained, and the rudder returned to neutral. The aircraft did not recover from the ensuing dive and impacted the ground in a nose down attitude at about 160 kts. There was an immediate fire that was quickly extinguished by the attending fire crew but the pilot suffered fatal injuries on impact.

The pilot had originally been trained to fly whilst serving in the Royal Air Force (RAF). During his RAF service he completed a three-year tour of duty as a member of the Red Arrows display team flying Hawk aircraft. After leaving the RAF he continued to fly professionally, initially with a display team flying a Pitts aircraft and latterly as an airline pilot. For the last three display seasons he had also flown a variety of historic aircraft on an occasional basis. He first flew the Kingcobra in April 1998 and had flown it in displays on at least 10 occasions since then and was known to have enjoyed flying the aircraft.

As a holder of an Airline Transport Pilot's Licence, the 43-year old pilot had a total of 7, 730 flying hours of which 13 were on type. He had flown 143 hours during the last 90 days and 56 hours during the last 28 days. The pilot held a current Display Authorisation (DA) for a Category C aircraft. The certificate of test had been renewed and was valid until September 2001. To maintain the validity of the DA the pilot was also required to carry out at least three display sequence practices, one in the same category of aircraft, in the 90 days preceding a display. During the required period the pilot had flown 30 minutes dual in a Harvard, 25 minutes of display practice in the Kingcobra on 1 June 2001 and the airshow display on 2 June. Relevant display practices were not recorded in the pilot's logbook but were recorded as having been carried out by the aircraft operator's organisation.

No evidence was found of any pre-existing disease or medical condition that could have contributed to the accident. A post mortem toxicological examination did not reveal any factors which might have influenced the performance of the pilot. Special attention was given to the possibility of carbon monoxide poisoning but the levels of carboxyhaemoglobin in the medical samples were insufficient to have had any effects of an incapacitating nature. Shortly before the accident, the pilot was observed by several witnesses to have been in good spirits and looking forward to carrying out his display.

The maximum continuous operating limits for the aircraft engine as stated on the Permit to Fly were 2,500 RPM and 40 inches manifold pressure (MP). These were also the limits used for carrying out aerobatics. The takeoff limits were 3,000 RPM and 46 inches MP and the recommended entry speed for looping and other vertical manoeuvres was 250 kts. The Centre of Gravity (CG) at the operating weight, including the pilot, was at the aircraft forward limit. Fuel load did not materially affect the CG position so the aircraft was normally operated at the forward CG limit.

The weather conditions were good for display flying except that both the surface and upper winds were towards the crowd. The surface wind was northwesterly at 10 to 12kt, visibility was greater than 10 km, cloud was broken at 1,500 feet and the air temperature was 13°C.

A large number of video recordings and still photographs were made available to the investigation and as a result, it was possible to reconstruct most of the display sequence flown by the pilot. It was not possible to make any direct comparison with his display on the previous day because only limited film footage was available and the weather conditions were different. The elapsed time from takeoff until the accident was seven minutes. One unsuccessful manoeuvre, which resulted in a departure from controlled flight, two minutes before the accident, was clearly observed and recorded on video film. The aircraft was quickly recovered and all the other manoeuvres until the final manoeuvre appeared to have been conducted normally but at slower speeds than might be expected.

Some sections of video allowed estimates of the aircraft's speed to be derived and manoeuvre entry speeds were calculated so that they could be compared with target entry speeds. These calculations showed that on the entry to the first loop, when all three aircraft were flying together, the speed of the Kingcobra was around 250 to 270 kts. Just before pulling up into the first manoeuvre from which a loss of control resulted, the speed was 210 to 230 kts. After this manoeuvre, airspeed was never again measured at above 200 kts. Later in the display, on the crowd flypast before the final manoeuvre, the speed was measured by two separate methods at 192 kts. The engine speed was also calculated at this point from recorded sound at 2,750 RPM.

During the final manoeuvre, control surface positions could be determined which showed full up elevator throughout. When the aircraft was inverted over the top of the manoeuvre with the nose about 30° below the horizon, there was a large input of right rudder and the aircraft responded by yawing to the right. Once the aircraft had departed into the incipient spin, the rudder returned to neutral. There was some movement of the ailerons during the dive and the aircraft rolled to the right before impact.

The Kingcobra was a single seat WW II fighter aircraft with tricycle landing gear and a laminar flow wing. It was powered by a 1,325 HP liquid-cooled piston engine which drove a hydraulically controlled, four-blade, constant speed propeller. The propeller was driven through a reduction gearbox at a fixed ratio of the engine crankshaft speed. The governor in the propeller regulator assembly, mounted on the rear of the propeller hub, controlled the blade angle to maintain the selected propeller RPM. The propeller was 11 feet in diameter and had a pitch range between 20° (fine) and 55° (coarse). The engine wa s located behind the pilot with a drive shaft running forward connected to the propeller gearbox. The landing gear and flaps were electrically operated. The flying controls were conventional and manually operated. The elevators and ailerons were operated by control rods and the rudder via control cables. A 'bag' type fuel tank of 66 US gallons capacity was located in each outboard wing section. The aircraft had been refuelled to full tanks on the previous day.

This particular aircraft was constructed in 1944 and after acquisition by the operator in 1991, having flown a total of 1,085 hours, it was completely dismantled. The airframe and all the systems were overhauled and a zero-timed engine, gearbox and new propeller were fitted. After the overhaul the aircraft first flew on 12 August 1994 and between August 1994 and January 2001, it had flown 73 hours. The most recent annual inspection for the 'Permit to Fly' renewal had been carried out on 24 May 2001 following which the aircraft next flew on 1 June 2001. Between that flight and the accident flight the aircraft had completed two hours flying.

The aircraft had crashed in a confined area to the west of the runway just within the airfield boundary, in a steep nose down attitude and on a heading of approximately 076°. The Pitot tube on the left wing was found embedded in the earth at an angle of 70°. The marks made on the ground by the wings indicated that the right wing had impacted first and there had been very little ground slide. The front section of the aircraft was buried in the ground to a depth of around one metre. The outer section of the left wing, including the left fuel tank, together with the right fuel tank, had become detached and were located approximately 13 metres from the main wreckage. There had been an impact fire around the fuel tanks which was extinguished by the Airport Fire Service. Both tanks still contained some fuel and there was evidence of fuel spillage on the vegetation nearby. The main wreckage was unburned apart from a small fire around the rear of the engine.

It was established that at impact the landing gear and flaps were retracted and the propeller blades showed some evidence of rotational scoring associated with high power, but no tip damage. The blade pitch mechanism had broken and no assessment could thus be made of propeller pitch angle from the site.

The wreckage was recovered to the AAIB's facility at Farnborough for a detailed examination. There was no evidence of any mechanical failure within the engine. The propeller regulator and the blade pitch change mechanism were examined; the initial dismantling was performed with the assistance of the operator's maintenance organisation and revealed no evidence of malfunction. The position of the regulator control lever indicated a position approximately midway between the fine and coarse positions. The angle of each blade was controlled hydraulically by means of a torque unit. The position of the piston within each unit was consistent with the position of the regulator control lever and showed a similar angle for each blade. Therefore, the propeller appeared to have been operating within the governed pitch range.

The needle on the propeller RPM gauge had struck the face of the instrument at a reading of 2,800 RPM which was consistent with the audio analysis of the video evidence. The tail of the manifold pressure gauge needle had also struck the face of the instrument, indicating a reading at impact of around 48 inches; this would represent an engine power above the maximum continuous setting. The throttle quadrant had been crushed in the impact; the throttle lever was in a mid position, the propeller lever was close to the maximum RPM position and the mixture control was at the idle cut-off position. However, these levers could have moved as the fuselage collapsed after the impact and so their positions were unreliable indications of pre-impact settings. The mixture control on the carburettor was at auto-rich, the normal setting. The extensive break-up of the airframe precluded an assessment of the possibility of a flying control restriction due, for example, to a loose article, but there was no evidence of any pre-impact disconnection.

Guidance concerning the regulation and organisation of flying displays is contained in Civil Aviation Publication (CAP) 403. This document contains a recommendation that at large displays, a Flying Display Committee should be utilised. It also states that at least one member of the committee should be positioned on the crowd line with direct communication to the Flying Display Director who holds the responsibility for control and modification of the flying display programme.

A Flying Display Committee was established at the airshow to monitor the display standards and ensure that the safety regulations were not infringed. A system was in place whereby a committee member could contact Air Traffic Control (ATC) and arrange for a display to be stopped if they considered safety was being compromised. Because the ATC tower was located on the opposite side of the runway from the crowd line, communication was to be by telephone or radio. On this occasion, during the Kingcobra's display, a committee member became concerned by the loss of control at the apex of the first rolling climb manoeuvre. The committee member attempted to contact ATC five times by radio and the Display Director twice by telephone but he was unable to get an answer. The high-speed display line was established west of Runway 03/21, 230 metres from the crowd line. The aircraft impacted the ground 100 metres further west of the display line.

It is difficult to understand why the pilot, who was experienced and practised in the display environment, continued with his display after experiencing a departure from controlled flight during one of the manoeuvres. If there was a problem with the performance or handling of the aircraft then it seems unlikely that he would have continued the display without reviewing the problem. This was, however, a large public display and it is relevant to consider the extra psychological pressures this could have exerted on the pilot. Nevertheless, the pilot had considerable experience of airshow displays and his associates had had no reason to question either his ability or his judgement.

Because of the constant need to check the positions of the other two aircraft, as well as his own position with reference to the display line, and make adjustments accordingly, the display task was more difficult than a solo display. The intention was to carry out a flexible series of individual manoeuvres and it would have required a positive trigger, such as failure to achieve a target airspeed or minimum height, to cause him to stop it prematurely. The absence of a pre-planned and practised sequence of manoeuvres could have contributed to the pilot's task of assessing the aircraft's potential to complete the next intended manoeuvre, but it should not have had a bearing on his decision to continue the display after the first incipient spin.

Analysis of the aircraft speeds from video footage showed that the final manoeuvre was probably entered with insufficient speed for it to be completed successfully. The lack of speed was most likely evidence of a continuing loss of energy during the display, partially as a consequence of the earlier failed manoeuvre. The aircraft engine at one stage was running at a higher RPM than recommended which may have been an attempt to regain the energy and airspeed.

The rudder and ailerons could be seen to move during the final manoeuvre but the elevator remained fully up. This would have required positive backpressure on the control stick to be maintained, or a jam in the control system. There was no evidence of the pilot having a problem with the flight controls earlier in the flight so it is more likely that the stick was held in this position. The flight control inputs at the top of the final manoeuvre, in particular the rudder, were not consistent with a display manoeuvre or a recovery action. In fact, they were similar to the control positions used to effect deliberate entry into a spin and the aircraft entered an incipient spin. From consideration of the evidence and the experience of the pilot, it seems likely that an unknown factor affected the pilot's physical and/or mental performance during the display.

Communication difficulties across the airfield were responsible for the failure of the system established by the airshow organisers to interrupt the display when required. After the accident, the event organisers installed a direct telephone line between the Flying Display Committee on the crowd side of the runway and the Display Director in the ATC tower. (AAIB Bulletin No: 4/2002 Ref: EW/C2001/6/4)

NTSB: CANADAIR SABRE 6 N3842J: EL TORO MCAS IN 1993:

Canadair Sabre N3842J. The aircraft was later marked 'Sabre Dance' by pilot/owner Jim Gregory. *(Jim Sterling)*

On May 2, 1993, about 1343 hours Pacific daylight time, a Canadair F- 86E Mark 6, N3842J, crashed during an aerial demonstration at the El Toro Marine Corps Air Station, Santa Ana, California. The airplane was being operated as part of an annual airshow when the accident occurred. The airplane, operated by the pilot in partnership with National Airshows Inc., was destroyed by impact and post-impact fire. The certificated commercial pilot, the sole occupant, received fatal injuries. Visual meteorological conditions prevailed. The flight originated from El Toro at 1341 hours.

An Operations Inspector, Federal Aviation Administration, Long Beach Flight Standards District Office, was present at the airshow. He reported that the pilot was to participate in a mock dog-fighting routine with the pilot's partner/operator flying another aircraft as a portion of the normally planned demonstration. The pilot of the second airplane did not feel well and cancelled his participation in the demonstration. The pilot of the accident aircraft then planned to perform a solo aerobatic routine. The routine that the pilot began was not one that had been practiced.

At 1318 hours, Air Traffic Control personnel cleared the accident airplane to taxi to the runway in preparation for the aerial show. Ground personnel working with the pilot reported that as the airplane taxied out from parking, the pilot's shoulder harness was observed lying back behind the seat back and unsecured. At 1324 hours, while waiting for takeoff, the pilot made a radio request for assistance with the airplane's canopy from his ground crew. A witness reported observing the pilot leaning far forward in the seat of the airplane on the right side of the airplane. At 1325 hours, the pilot cancelled any assistance from his ground crew and at 1341 hours, the pilot was cleared for takeoff on Runway 34L.

After departure, the pilot performed a right 90º climbing turn, followed by a left 270º descending turn. This positioned the airplane over Runway 16R at about 75 feet above ground level (AGL). The pilot then began a loop with an aileron roll at the top of the manoeuvre. Following the descent at the bottom portion of the loop, the airplane descended in a near level attitude until striking runway 16R about mid-field. An intense explosion occurred. Wreckage was scattered along the runway for about 1/4 mile. No spectators were injured.

The operator reported that the loop in the accident airplane required a minimum of 275 knots at the entry point and a minimum altitude of 4,000 feet above ground level (AGL) at 125 knots at the top of the manoeuvre. The operator indicated to FAA personnel that he observed the accident airplane's manoeuvre and that it appeared to him that the accident airplane did not have the minimum entry speed. The operator estimated that the maximum altitude gained at the top of the manoeuvre was about 2,500 feet and the airplane appeared to experience an accelerated stall at 100 to 200 feet AGL just prior to impact. Additionally, the operator indicated that it was normal for the pilot to wear a “G” suit during his aerobatic routine.

The pilot held a commercial pilot certificate with airplane single engine land and sea, airplane multiengine land (limited to VFR only), and instrument-airplane ratings. The most recent second-class medical certificate was issued to the pilot on April 9, 1993, and contained no limitations. The pilot's airman records, maintained in the FAA's Airman and Records Center located in Oklahoma City, were reviewed by Safety Board investigators. The review noted that pilot was first issued a student pilot certificate on May 18, 1976, followed by a private pilot certificate on May 25, 1976. The pilot then received a commercial pilot certificate on July 21, 1976. The pilot held a letter of authorization (LOA) to act as pilot-in-command of North American F-86 Sabre Jets (All Models).

The operator reported that the pilot's formal aerobatic training was unknown but that the pilot had owned and flown aerobatic aircraft in aerobatic flight in the past. The pilot received a checkout in the accident airplane on January 10, 1992, and the pilot completed all approved manoeuvres by January 15, 1992. During 1992, the pilot did not fly any aerial demonstrations, however, he did practice the F-86 solo routine several times, down to ground level. In 1993, the pilot prepared for solo and dual airshow routines by practicing in a Pitts S-2 and the accident airplane. The operator indicated that practice sessions exceeded 25 sequences.

The operator reported that the pilot portrayed himself as an ex-naval aviator and A-4 pilot. U.S. Naval Investigative Service (NIS) personnel assisted Safety Board investigators in an inquiry of the pilot's military experience. According to the NIS, the pilot was terminated from the U.S. Navy advanced jet-training curriculum, Pensacola, Florida, on May 19, 1976.

Review of pilot logbook entries submitted by the operator revealed that the pilot's total aeronautical experience consisted of about 5,596.4 hours, of which 47 were accrued in the accident airplane. In the preceding 90 and 30 days prior to the accident, the logbook lists a total of 26.8 and 24.5 hours, respectively, flown in the accident airplane. On the last application for medical certificate, dated April 9, 1993, the pilot listed a total time of 6,200 hours, with 150 hours accrued in the preceding 6 months. The application did not have any entry for military experience.

Pilots participating in aerial demonstrations are required to demonstrate to the FAA their competency. The FAA utilizes airshow professionals as Airshow Certification Evaluators (ACE) to evaluate other airshow performers for the purpose of recommending a performer for aerobatic flight. The ACE program is administered by the International Council of Airshows Inc (ICAS) and evaluations and recommendations are forwarded to the FAA for review. The FAA is the final authority to issue a Certificate of Acrobatic Competency, Form 8710-7. An FAA statement of acrobatic competency is valid for 1 year and an ACE has evaluation authority through ICAS Inc. that is valid for two years.

Safety Board investigators examined the evaluation records of the pilot and those of his last evaluator that are maintained by ICAS Inc. The pilot received an initial evaluation of acrobatic competency on September 19, 1991, by an ACE. The FAA issued a Form 8710-7 for solo and formation manoeuvres in Pitts S-2 aircraft, with a level 2 (250 feet) altitude limitation to the pilot, with an expiration date of September 30, 1992. The evaluator indicated that the pilot's initial qualification at level 2 was based on the pilot's prior military low level and air-to-ground experience.

On October 19, 1992, the pilot applied for a statement of acrobatic competency with a level 1 (no restriction) altitude. The pilot was evaluated again by the same evaluator on January 4, January 18, and January 19, 1993, in a Pitts S-2 airplane. Additionally, the evaluator observed the pilot in formation flight in the F-86 with a MiG-15 on February 9, 1993. A review of the pilot's logbook indicated that the pilot logged flights in the Pitts on January 12 and January 18, 1993.

On February 24, 1993, the pilot was given an ACE acrobatic competency recommendation to the FAA with the following limitations: Manoeuvre limitations - solo/formation; Altitude limitations - Level 1, surface; Authorized aircraft - Pitts S-2, F-86 Sabre. A Level 1 authorization means that a performer may conduct aerobatic manoeuvres down to the surface, not having any other altitude restriction for termination of a manoeuvre. On February 26, 1993, the FAA issued a statement of acrobatic competency (FAA Form 8710-7) to the pilot.

The pilot's evaluator submitted an application for designation as an evaluator on March 1, 1991, and listed 8 years of airshow performance experience. He was again evaluated on October 17, 1992, by the operator of the accident airplane for an ACE renewal. The evaluator held an FAA Form 8710-7 that expired on March 31, 1994.

FAA personnel interviewed the pilot's evaluator who recommended him for his aerobatic competency. The evaluator, a member of an aerobatic team and an employee of National Airshows Inc., indicated that on the preceding two days before the accident, the pilot exhibited poor control or judgement when he utilized an unusually low altitude to terminate manoeuvres during his airshow performances. The evaluator indicated that he counselled the pilot about his performance and thought the issue resolved.

The airplane had accumulated a total time in service of 1,666.8 flight hours. Examination of the maintenance records revealed that the most recent airframe and engine inspection was accomplished on February 3, 1993, 24.8 flight hours before the accident. The engine had accrued a total time in service of 132.9 hours of operation since being overhauled on August 1, 1977. Examination of the maintenance records revealed no unresolved maintenance discrepancies against the aircraft prior to departure.

The closest official weather observation station is located at the El Toro Marine Corps Air Station. At 1345 hours, a surface observation was reporting in part: Sky condition and ceiling, 20,000 feet scattered; visibility, unrestricted; temperature, 77ºF; dew point, 55ºF; wind, 150º at 3 knots; altimeter, 29.88 in Hg. Review of the air-ground radio communications tapes maintained by the El Toro Marine Corps Air Station facility revealed that the aircraft successfully communicated with the ground and local control positions.

Examination of the airplane by FAA personnel revealed that the seat belt attachment fittings were both securely fastened to the seat; however, both halves of the seat belt were consumed by fire. The seat belt buckle was found in the fastened position; however, the seat belt material was consumed by fire. The shoulder harness was consumed by fire with the exception of about 4 inches of harness material remaining in the inertial reel mechanism. The shoulder harness inertial reel mechanism was in the unlocked position and when tested, the reel functioned properly. The aircraft canopy was found in the closed position.

A post mortem examination of the pilot was conducted by the Orange County Coroner’s Office on May 3, 1993. According to the report, the cause of death was attributed to exsanguination (excessive loss of blood due to internal or external haemorrhage). No pre-existing conditions were noted during the post mortem examination which would have adversely affected the pilot’s abilities to pilot the airplane. An external examination of the pilot by FAA personnel at the accident site revealed that the pilot was not wearing a “G” suit.
Toxicological examinations were conducted by the FAA Civil Aeromedical Institute (CAMI) on May 12, 1993, and revealed the presence of 14.4 ug/ml Salicylate, the main ingredient of aspirin in the urine.

The airplane’s altimeter was examined by the National Transportation Safety Board’s Materials Laboratory Division. An external examination revealed that the outer case was covered by black sooting and the glass face of the instrument was broken and missing. Detailed visual examination of the dial face under the bottom portion of the 100 foot and 1,000 foot pointers revealed impressions (witness marks) directly beneath the pointers. With the pointers aligned over the witness marks, the altimeter indicated an altitude reading between a minus 20 and minus 30 feet. The Kollsman window barometric scale could be rotated by the adjustment knob. Examination of the internal components revealed that the pivot screw was displaced from the centre of the jewel bearing of the rocker shaft and the face of the rocker shaft contained an impact mark adjacent to the position of the pivot screw.

A video tape recording of the accident was submitted to the National Transportation Safety Board’s Engineering Services Division. Safety Board investigators reported that at the start of the final manoeuvre, the airplane passed the viewing stand at an altitude of 75 feet AGL and at 350 knots ground speed. At the top of the loop, the airplane reached an altitude of about 3,650 feet. The speed at the top of the loop was not determined.

As the airplane approached the ground, the speed had increased to 380 knots and then slowed to about 360 knots at ground impact. The airplane descended to about 75 feet and then pitched down. The angle of attack at 75 feet was about 16º and then dropped to 8º at ground contact. The pitch angle at 75 feet was about -3º and then dropped to about -5º at ground contact.

Calculation of acceleration loads during the last quarter of the loop indicated that the pitch change rate was about 20º/second, which equates to about 6.4 Gs. During the last second before impact, the pitch angle changed from -25º at 350 knots, to -6º at 370 knots. The total flight load for the last second was about 7.3 G. The wreckage was initially released to representatives of the owner on May 5, 1993. The altimeter was released on October 5, 1993. No wreckage or parts were retained by the Safety Board.

Air Accidents Investigation Branch

P-38J LIGHTNING: DUXFORD 13 JULY 1996

This particular accident could be regarded as a watershed event in the UK Airshow Circuit being part of a particularly bad safety year for display flying in the UK, a total of four fatal accidents occurring. It was literally the ‘straw that broke the camels back’ forcing the CAA to establish a Civil Air Display Review Group in the United Kingdom.

The legendary P-38J Lightning was performing at the ‘Flying Legends’ Air Display at Duxford, which was being staged over the two days of the weekend of 13/14 July 1996. The display on 13 July was completed without incident. On 14 July, the aircraft had taken off at 1435 hrs as the lead aircraft in a formation comprising one Curtiss P-40B Tomahawk and one Bell P-63 Kingcobra fighter aircraft. The display ‘slot’ commenced at 1439 hrs and after several formation passes in front of the assembly of spectators, the trio split up in order to enable each aircraft to carry out a solo display.

The P-38 was the final aircraft to perform its solo routine and was due to clear the display area by 1455 hrs. The aircraft commenced its run-in from the east of the airfield, in a shallow dive to gain speed, then carried out a loop. This manoeuvre was followed by a ‘Cuban Eight’ which involved two short periods of flight under negative ‘g’.

At the end of the ‘Cuban Eight’, the aircraft was passing from east to west (crowd left to right), pulled up and to the left initially, levelled the wings, then performed a 270° roll to the left. The aircraft then came back to pass across the front of the crowd from west to east. With the aircraft appearing to be at a normal entry height and speed, an aileron roll to the left was commenced as the aircraft crossed the western threshold of runway 06. The first 360° roll was completed normally but the aircraft continued, without pause, into a second full roll. While the aircraft was inverted in this second roll, the nose dropped towards the ground and the aircraft began to lose height while the roll continued. By the time the aircraft became upright again, it had descended to a very low height above the runway. The aircraft continued to roll left and struck the runway with its left wing and approximately 30° of left bank applied, about two thirds of the way along runway 06.

The left outer wing ruptured and collapsed, followed by the impact of the left engine. At this time, a large fireball erupted as the aircraft began to cartwheel across the airfield, breaking up into multiple segments as its trajectory took it diagonally away from the main spectator area towards a row of parked light aircraft on the south side of the airfield. Several of these aircraft were destroyed or severely damaged in the wreckage’s path. One of the engines bounced further than the rest of the wreckage, crossing the airfield boundary and then the M11 Motorway which runs almost perpendicular to the end of the runway. A passing freight truck sustained some minor damage from pieces of wreckage but was able to continue travelling northwards along the motorway. The engine came to rest in a field just to the east side of the motorway, close to where several members of the public had been standing in order to watch the flying activities from outside the airfield boundary.

The airfield Fire and Rescue services were quickly at the scene and brought the numerous areas of fire under control in a short time. The pilot was found in the seat amongst the wreckage of the main fuselage pod with his four point harness still fastened. A post-mortem examination found that the pilot had been killed by a severe head injury. No physical condition was found which could have caused any incapacitation of the pilot and no traces of drugs or alcohol were found to be present. It was assessed that the destruction of the cockpit was such that survival was impossible. The pilots and passengers of the visiting light aircraft had been required by the airport operator to move to the spectator side of the runway in order to watch the air display and fortunately, there were no injuries to any spectators.

The display routine followed by the P-38 formation was identical to that flown at the display on the day prior to the accident. The significant difference was that during the Saturday display, only a single 360° aileron roll had been carried out, but at the time of the accident two consecutive 360° rolls had occurred, with a continuation past the wings level at the end of the second roll. The weather at the time was a surface wind from 270° at 6 kts, variable in direction between 240° and 300°, visibility in excess of 10 km, scattered cloud base 3,000 feet, QNH 1026 mbs.

Photographs and video coverage of the aircraft's manoeuvres were analysed with a view to assessing not only the pre-impact flight path characteristics but also the pre-impact aircraft integrity and the operation of aircraft systems. A full flight path analysis was carried out using several video sequences which had been filmed from a variety of viewpoints. Analysis of the single aileron roll flown during the previous day of the show, revealed that the time taken to complete the roll on this occasion was 3.4 seconds and it was noted that the aircraft had an upward trajectory throughout this manoeuvre.

The analysis of the accident coverage showed that the aircraft had performed two continuous aileron rolls, taking 4.4 seconds and 3.6 seconds respectively to complete. A time difference of 0.8 seconds is significant in terms of roll rate, approximating 80º of roll angle at 100º/seconds. The rolls had been started at a height of about 250 feet above the runway, at a speed of about 250 knots and with an initial nose-up pitch attitude. The roll to the left was initiated by a rapid roll control input which produced a considerable aileron deflection. This aileron deflection remained essentially constant until the aircraft had completed approximately 675° of roll, at that point, the ailerons were returned to the neutral position where they remained until the aircraft struck the ground.

During the first roll the aircraft climbed to an apogee of about 360 feet when inverted, descending to about 260 feet by the time it was erect again, a loss of 100 ft. At this point the aircraft pitch attitude was very slightly nose-down. There was no pause before the second roll was executed. During this roll, the nose dropped progressively and an increasing rate of descent developed. At the inverted position, the aileron position was observed to be maintained in the almost fully (left roll) deflected position and a considerable elevator displacement in the 'stick back' sense was made. Considerable left rudder control was also added at this time and the roll rate increased. Approximately 45° of roll angle before the aircraft reached the erect attitude, the rudder and aileron inputs were moved to neutral, but were not applied in opposition to the roll. The roll rate increased slightly as the aircraft rolled through wings level (from about 110°/sec to 125°/sec), with a rate of descent of about 7,200 feet per minute, to the point of impact. Ground speed at impact was assessed as 230 kts with the final angle of descent of 14.5° giving a speed along the flight path of 238 kts.

Impact was seen to occur on the left wing tip at an attitude of about 30° left roll with the fuselage level in pitch. The aileron and rudder positions were approximately neutral and the elevator was deflected up. An analysis of the propeller speeds from video showed that they had remained constant throughout the rolling manoeuvre. Both propellers were turning at about 1,300 RPM, the right slightly faster than the left. With the engine propeller reduction gearing ratio of 2:1, this accorded with the aircraft operating limitations which quoted the engine limits for use in aerobatic manoeuvres as 2,600 RPM/40 inches manifold pressure.

The aircraft had struck Runway 06, straddling the centreline and about 450 metres short of the eastern end. The initial impact had been with the left wingtip on the runway and the sequence of marks of the immediately subsequent impacts, was consistent with the aircraft being on a heading of approximately 079°M (the runway heading is 062°M), in a substantially level pitch attitude and significantly banked to the left. Examination of the cuts made by both propellers in the runway surface indicated that both engines were developing considerable power and that the aircraft had a high rate of descent. Initial assessment of the propeller marks, without making allowances for rate of descent, indicated that the aircraft had struck the ground with engine speeds of the order of 2500 RPM associated with a ground speed of about 200 kts.

After the initial impact, the left outer wing, empennage and both tail booms separated from the remainder of the airframe which yawed sharply to the left before crossing the southern edge of the runway and cartwheeling across the grass. The main wreckage came to rest, inverted, in a wheat field, about 420 metres from the point of initial impact, just outside the southern boundary of the airfield. Both engines detached from their mountings after impact; the right had been thrown 60 metres beyond where the main wreckage came to rest and the left, 180 metres beyond, crossing the M11 Motorway. Although the aircraft burst into flames very shortly after the initial impact, there was little evidence of significant fuel spillage between the point of initial impact and where the main wreckage came to rest, there being only isolated areas of blackened grass.

There was no evidence of any pre-impact structural distress of the airframe or loss of attachment of control surfaces. There was no evidence of pre-impact loss of integrity of the control systems, all damage being consistent with the nature and degree of structural break-up after impact. The extent of the disruption to the control systems precluded eliminating the possibility of any transient obstruction of the systems. Assessment of the scrape marks on the left outer wing and aileron made during the initial contact on the runway, showed that the aileron had been at a substantially neutral position at that moment. Damage on the left end rib of the elevator and on the closing rib at the left end of the tailplane cut-out, indicated that the elevator had been deflected up at the time the left fin base struck the runway.

The aileron boosters were examined. The position of the by-pass control piston of the left booster showed that when it became disrupted at the time of impact, hydraulic pressure had been available. Damage to the input rod of its control valve indicated that there had been no aileron movement demand at that time and damage to the output rod of the actuating cylinder was consistent with its being at a neutral position. All damage to the left and right booster assemblies was consistent with the damage to the structure to which they were attached and there was no evidence of any pre-impact failures.

The pilot held an Airline Transport Pilot's Licence and was type rated on Boeing 737 series, Boeing 757/767 and Piper PA-23/34/44 series aircraft. He was a Captain with a UK charter airline flying Boeing 757 and 767 aircraft and was the Chief Pilot for the operator of the P-38, responsible for the crewing and operation of a varied fleet of some 15 vintage 'warbird' aircraft types.

The pilot was also the Airshow Display Co-ordinator for the 'Flying Legends' display at Duxford, being responsible for the planning of the display items and for the choreography of the show finale, which also involved leading a mass flypast of some forty historic aircraft. He gave the daily display briefing to the participating pilots and undertook some in-show replanning on the Sunday afternoon when the planned show sequence was interrupted by the arrival of a significant display item almost an hour ahead of the planned schedule. This undoubtedly added to the pilot's workload for the afternoon. Shortly after this, the pilot participated in the show in the lead aircraft of a pair of DH89A Dragon Rapides. After landing from this, there was then some twelve minutes before he then taxied out in the P-38 for the start of that display item.

The pilot was operating the P-38, an aircraft registered in the USA, under the privileges of his FAA Commercial Pilot's Licence. Under normal circumstances, as the aircraft maximum take-off weight was in excess of 5,700 kg (12,500 lb), a specific aircraft type rating would be required. In this case, the pilot held a letter, issued by the FAA Flight Standards District Office in Oakland, California during 1988, which authorised him to operate as pilot-in-command in experimental category aircraft - *"All types and makes of high performance piston-powered aircraft."* The letter also noted that it did not, in itself, authorise the performance of aerobatics in airshows. A separate authorisation for this activity is required, but only in respect of participation at airshows within the USA.

The FAA indicated that the documentation held by the pilot did comply with the appropriate US Federal Aviation Regulations and the special operating limitations for the aircraft during this flight. However, the FAA did note that since the issue of the letter of authority, the procedures had since been changed to reflect current requirements, but the letter remained valid. The pilot held a CAA Display Authorisation (DA) covering many aircraft types including the P-38. He also held an appointment as a Display Authorisation Evaluator on behalf of the CAA.

The pilot's DA had a current validation and permitted the performance of flypasts down to 30 feet agl and aerobatic manoeuvres (in certain types) down to 100 feet agl. For the P-38, the minimum aerobatic height was specified as 200 feet agl. Formation flying was also permitted. From the video evidence available, it was apparent that the pilot commenced the final rolling manoeuvre at a height which was in accordance with his DA.

On the Saturday, the day prior to the accident, the pilot flew a similar display profile but with only one aileron roll at crowd centre. Some minor transgressions of the pilot's DA limitations were noted by the attending CAA Air Display Inspector, notably in terms of the minimum aerobatic height during the aileron roll and for being marginally inside the minimum lateral separation distance appropriate for aerobatics. Both of these comments were made by the Inspector to the pilot after the event and the pilot gave assurance that the Sunday display would fully conform to the DA limitations.

The pilot had conducted a display practice in the P-38 on 11 July and had flown in the public display on 13 July. In the 28 day period prior to the accident, the pilot had also flown each of the following types: Boeing 757, Spitfire V, Hellcat, Skyraider, Bearcat, Rapide, Aztec, Baron and Cub.

The aircraft was manufactured during 1943 at the Lockheed Aircraft Factory in Burbank, California and had the serial number 42-67543. It operated in service with the United States Army Air Force until being discharged in February 1945. It was found by its current owner in a derelict state in Texas in 1988. After purchase, it was taken to California and restored to flying condition. Test flying was carried out early in 1992 and the aircraft was imported into the UK during the summer of that year. Since then, the aircraft had operated under a CAA Exemption to the Air Navigation Order which permitted the aircraft to fly without a valid Certificate of Airworthiness for the purposes of Demonstration and Exhibition flying only, provided that the FAA Special Airworthiness Certificate and Operating Limitations dated 9 January 1992 were current.

The FAA Special Airworthiness Certificate was issued in January 1992 in the Experimental category, for the purposes of Exhibition flying and was current at the time of the accident. The aircraft was being operated in accordance with the Operating Limitations document. The aircraft's maintenance documents showed that it had been correctly maintained in accordance with the FAA requirements and had been properly certified by an FAA approved licensed engineer. The FAA Certificate of Registration was issued on 21 February 1992 to an owner with an address in Las Vegas, Nevada.

The aircraft was also subject to an exemption issued by the CAA in order to allow it to operate at speeds greater than 250 kts while below 10,000 feet. A current Aerial Work Operating Permit for the aircraft had also been issued by the Department of Transport. The pilot had compiled a set of aircraft operating notes for the P-38, which indicated that, for aerobatics, the engine limits were 2,600 RPM and 40 inches manifold pressure (the maximum continuous power setting for the aircraft), the entry speed for rolling manoeuvres was 200 kts and that no negative 'g' manoeuvres were permitted because of possible hydraulic problems. It was ascertained that a previous occurrence of negative 'g' had caused a hydraulic aeration problem which prevented the landing gear down function and required manual hand pump operation to recover. It was also indicated that the preferred rolling direction was to the left in order to prevent the unlocking of the nose landing gear door mechanism, which was known to have occurred during previous rolls to the right. These hydraulic problems were not known to have caused any adverse effects in the aileron booster systems.

Information from the aircraft's Maintenance Instruction Manual states that with aileron hydraulic boosters operating, the pilot's control input applies one sixth of the total aileron load. The implication of this is that, in the event of a failure of the hydraulic booster system, the aileron control forces felt by the pilot would be six times greater than normal for a given aileron deflection under the same flight conditions. From examination of the aileron booster system, it is considered that, in the event of a hydraulic failure while the ailerons were deflected during the rolling manoeuvre, the aileron deflection would have tended to reduce as a result of the aerodynamic forces.

Copies of the original 1944 Pilot's Flight Operating Instructions for this type of aircraft were also available. These contained the following relevant extracts:

"AILERON CONTROL HYDRAULIC BOOSTER - ...On these airplanes most of the aileron control force is provided by hydraulic boost; the remainder is applied by the pilot. Control cables which control the boost mechanism are mechanically connected to the control surfaces, allowing manual flight control in an emergency. The aileron boost shut-off valve is located on the right side of the cockpit near the pilot's control column. In addition to this valve an automatic by-pass valve is incorporated in the mechanism to allow free movement of the ailerons in case the hydraulic pressure should fail."

In the "Flight Restrictions" section, it was noted that "Snap Rolls" and continuous inverted flight were prohibited. The section also contained the cautionary note: *" Extreme care must be taken during acrobatic manoeuvres which require a downward vertical recovery. Acrobatics should not be attempted at altitudes below 10,000 feet."*

Evidence was obtained which showed that the aircraft had successfully completed a double rolling manoeuvre in the past, with a significant upward trajectory apparent throughout. However, the majority of other pilots, who also flew aircraft belonging to the same operator, indicated that a single aileron roll manoeuvre was by far the more common. This view was supported by Air Display Inspectors from the CAA.

Consideration of the flight profile indicates that the start of the final manoeuvre occurred over the western end of the hard surfaced runway. At the end of the first roll, the aircraft was still in a location which was to the right (west) of the centre of the crowd. It is considered unlikely that the pilot would have intended to stop manoeuvring at this position as the display would then have appeared 'asymmetric' from the crowd's viewpoint.

It is known that the pilot was a very experienced display pilot and produced high quality, aesthetically pleasing displays. There is no evidence to explain why the aircraft entered the second part of the final manoeuvre in a less than optimum pitch attitude which developed into a significant downward trajectory. The possibility of a temporary restriction to the flying controls (especially the roll control), or some other form of distraction of the pilot, could not be dismissed.

In response to this and several other UK air display accidents which occurred during the 1996 display season, the CAA set up a Civil Air Display Review Group. The group identified some eighteen areas for detailed investigation and comment, covering many aspects of display organisation and participation. The work of the group is continuously ongoing but relevant recommendations are implemented, either by means of amendments to CAP 403 or by other means, in time for the start of the next display season. There was also an intention for the CAA to develop additional guidance material for display pilots in a similar fashion to the RAF Flying Display Notes. In view of the Review Group activity undertaken, AAIB considered that no further Safety Recommendations were necessary in this case.

Of course after any accident, the state of mind of the pilot is an important crash investigation consideration. Not having been present at the accident, but reading the proceedings of the Accident Board, an aviation psychologist raised the question of 'negative transfer' due to the number of different aircraft that this pilot had been flying at the time - he transferred from one to another type within twelve minutes at the airshow. This phenomenon can occur when an experienced pilot flies one type of aircraft, but due to his comfort zone being on one specific aircraft type, or prior and recent conditioning, transfers the actions required in one aircraft, to another. This is typical during high stress or high mental work-load tasks, where automatic behaviour takes over.

The information processing that occurs is where we use semantic memory, "that which should happen as planned according to short-term memory", as opposed to episodic memory, which is "what we normally expect to happen next". In this case the pilot intended using semantic memory in doing one roll, while his episodic memory took over and allowed for two rolls. This is due to normal reliance on the motor memory which allows us to carry out many skill based actions which through practise no longer requires central processing capacity, which frees up the memory and the central processing capacity to concentrate on other more immediate tasks. Had the pilot been thinking of some task that he may still have to do once on the ground, this thought could have captured his central processing, passed the roll manouevre over to his motor memory and subsequently the episodic memory, while his active thoughts were on the problem at hand. He may have done two rolls in his previous aircraft or just seen someone do two rolls and subsequently carried out this action. One will never know with any certainty.

SAAF MUSEUM SPITFIRE #5518: 15 APRIL 2000

In March 2000, the SAAF Museum's Spitfire display pilot resigned leaving only one other pilot, Lt Col Neill Thomas that had flown the aircraft previously. Unfortunately he had only maintained proficiency on the aircraft and not display currency since he was also the P51-D display pilot. Because of the dissimilar characteristics, the pilot did not mix flying the two different aircraft at display level. He had been flying the P-51 regularly and was in the process of handing over the display flying of the Mustang to another Reserve Force pilot, Col Jeff Earle and he would then take over the lead display role on the Spitfire. The Spitfire at this stage was in for a minor service and only became available for practice two days before the airshow on 15 April 2002.

Lt Col Neill Thomas, Commanding Officer and display pilot of the SAAF Museum described the events leading up to the non-fatal accident of the SAAF Museum's only airworthy Spitfire. "The other Spitfire (ZU-SPT), privately owned by Andrew Torr, was only available that day for a duo practice so we briefed on our sequence and I took off in the number two position which I maintained for the duration of the flight. ZS-SPT was a standard MK IX and was not fitted with the extra weight of two 20mm cannon but had the added disadvantage of clipped wings which resulted in a 10 MPH increase in airspeed performance. #5518, on the other hand, had the restriction of a limit on boost due to the age of the propeller and max boost was limited to 8 psi (75% of the available 12 psi) but SPT had no such restrictions. During the practice I had struggled to maintain station with the other Spitfire but attributed this to the fact that I had not flown formation with the Spitfire for six months and the Mustang was far heavier on the controls but more responsive to throttle movement than the Spitfire. The landing was normal and all power checks and temperatures and pressures during the flight were normal.

For those who don't know the Spitfire's fuel system, the mixture is automatically controlled ON or OFF, and has no fuel pressure gauge. The throttle is mechanically linked to the fuel injector carburettor which has automatic mixture settings. When the throttle is opened past a certain mechanical position, the mixture is automatically increased to full rich and a further movement of the throttle results in the mixture being increased to emergency rich. At idle, the boost is -4 psi and a 50% movement of the throttle increases the boost to 4 psi (a normal flight boost), from 4 to 8 psi uses 40% of the remaining movement and a small movement of the throttle is required to get to 12 psi; it is very easy to overboost the engine during close formation manoeuvring. The selection to emergency rich is not dependant of the actual boost pressure in the system and is a function of mechanical movement of the throttle lever only.

I was planning a solo practice for the Friday but received a call from Colonel Earle to inform me that the SAAF Association conference was running late and he would not be able to practice for the show, this in contradiction to the stated SAAF policy of "no practice, no fly". I was at this stage happy with the Spitfire practice the day before and cancelled the Spitfire sortie to rather practice in the Mustang.

At this stage, it may seem irrelevant, but the Surgeon General of the SANDF had suddenly passed away and his funeral was scheduled for the Saturday morning of the airshow at a venue very close to the Zwartkops airfield. On Friday I received a call to say that the Chief of the Air Force was concerned about the noise that could interrupt the funeral proceedings and cancelled all flying between 10h00 and 13h00. I approached his PSO and it was agreed that no jets would fly during this period and early on Saturday morning, I received a call to say that CAF wanted a noise check at 08h30 over the field to ascertain if the aircraft noise could be heard at the funeral site. This was done in the midst of the final aircrew briefing and all the last minute emergencies that usually have a habit of occur during any airshow.

As the Commanding Officer of the Museum I also hold the title of airshow host to all the VIP's that attend the airshows and at 09h30 I was at the VIP enclosure. I proceeded to the flight line and for some or other reason, pre-flighted the MUSTANG for the duo show with the Spitfire, instead of the Spitfire - had I only continued this mistake. I then met with Torr, the other Spitfire pilot and we briefed the profile to be flown in detail as well as the fact that I had been struggling to keep up with him during the rehearsal. At 10h12 we walked out to the two Spitfires and while strapping in, I realised that my helmet was not hanging over the cockpit side rail where I had left it. I looked to my left and there it was, hanging on the Mustang's side rail which I had inadvertently pre-flighted earlier.

I asked the groundcrew to fetch it, climbed out and then pre-flighted the Spitfire, climbed back in, started and taxied out behind the lead aircraft. The take-off, join-up and the few minutes spent holding for our slot did not provide any hints of the impending problems since I had easily maintained a loose formation position, awaiting the call to run-in.

Air traffic control called the formation in at 10h19 and I closed up in the descent for the first high speed flypast, station keeping was easy until the lead aircraft commenced with a wingover to the right for a steep turn away from the crowd. It was reasonably bumpy and I only got back into position at show centre as Torr called the turn to the left. Halfway through the turn I was struggling to keep up and was increasing throttle to maintain 8 psi boost. I was frequently checking boost and coolant temperature and with the boost still marginally below 8 psi, I did not notice any abnormality between throttle position and boost.

An eye witness on the ground (an ex-Spitfire pilot) noticed black smote intermittently appearing from the right exhaust but he was not near a radio and started to run towards the control tower 120 metres away. (SAAF DFS)

Concentrating on keeping station with the lead aircraft, the exhausts spat out increasing lengths of black smoke (symptomatic of a an over-rich mixture) and as we passed crowd centre for the second time, Torr called the pull-up for the wingover to the right. Once again I again fell behind again as he pulled up and as the formation passed through 600 - 700 feet AGL, the first indication of the engine failure was the sudden pull away of the lead aircraft and the nose of my Spitfire dropping rapidly below the horizon.

As the engine failed and the nose dropped, I immediately realised that the aircraft had suffered a catastrophic engine failure and thus lowered the nose as the airspeed was already decreasing through 150 mph (Spitfire best glide speed). I closed the throttle, called MAYDAY on the BOX frequency, switched to Tower frequency and repeated the Mayday call. I don’t recall receiving any response from the tower but Spitfires radios are known for poor reception due to the high cockpit noise level (an audio boost button is fitted on the RIGHT side of the cockpit to enhance reception, very handy when you are controlling the throttle with your left hand and the stick with your right) so that was no help.

I knew the runway was below and to my right, I dropped the right wing slightly and there was Swartkops; 6250 feet of tar runway, right in the position I had practiced numerous forced landings from during the two years I had been flying the aircraft. A better place to have an engine failure you could not get, apart from being on the ground that is. I had practiced forced landings in a configuration recommended by the Battle of Britain Memorial Flight and had in most cases, overshot the intended landing point during the practices.

My first thought was that I could make the runway easily. Of the approximately forty-nine Spitfires in the world flying at that time, forty-eight were fitted with the factory fit air bottle that blows the undercarriage down in a second or two in an emergency, only one was fitted with a modified Impala (Aermacchi MB-326M) emergency system requiring ninety cycles of the emergency undercarriage extension pump handle to lock the undercarriage down, you guessed it, Spitfire #5518 had this system. My initial thought was to get the gear down while I still had height, I selected the undercarriage down, the indicator lights went red and I then turned to the engine failure to try and ascertain what was wrong. I still did not know about the smoke which would have told me to pull the mixture to idle cut-off to clear the engine, the exhaust stacks are not visible from the cockpit and I checked the gauges, no fuel low pressure light, temperatures normal, fuel quantity almost full, engine RPM 600 odd.

I advanced the throttle and the engine responded for a second or two before cutting again, indicating that the cause of engine failure was related to the fuel supply to the engine. I pulled back the RPM lever and tried the throttle again, this time the response was less and the engine cut quicker, confirming a fuel problem. At this stage, six seconds had elapsed since the engine cut and was turning onto final approach to the runway when I noticed the threshold sliding slowly UP the windscreen, speed was 150 MPH and it was at this stage that I realised that I was not going to be landing on any runway. I turned the aircraft away from the airfield towards what I thought was clear area but the higher rate of decent (in excess of 4,000 feet per minute) had caught me unawares and in front of me was a large town house complex with the impact point somewhere in the middle. This left me no choice but to turn back towards the only open ground, a patch of grassy area 300 metres wide and no more that 100 metres in length, sloping at a angle of at least 15º to 20º (had I known the size of the rocks in this area I would probably have had a heart attack right there).

The SAAF Museum Spitfire was a write-off and required £1 million to restore to flying condition again. (SAAF DFS)

I selected full flap, unloaded the aircraft and tried to drag her up the hill by blipping the throttle but it very soon became apparent that I had become a passenger in my own aircraft and that I now had very little input left to determine mine, or her fate. One last look at the airspeed dropping thought 70 MPH, I pulled hard back on the stick and braced myself for what I though was the final seconds of my life. The only thought going through my mind at that stage was that I had not said goodbye to my boys who were watching the show at the time. All that happened in 17 seconds!

The aircraft impacted the ground tail first with a nose up attitude of 18º, the tail hit a rock the size of a Mini-Minor and dislodged it sideways before the tail broke off, slewing the aircraft slightly to the right and causing the right wing to drop to just above the ground. At this point the nose impacted the airfield's eight-foot high concrete security wall followed very shortly thereafter by the left wing, undercarriage and the right wing, the wall collapsed and the aircraft burst through the wall coming to a rest forty-five feet from the point of initial impact and two-feet away from a rock the size of a truck.

In July 1998 I was on the same airfield when a Piston Provost crashed during a display practice after failing to recover with sufficient height from a stall turn, skidded to a stop and the cockpit burst into flames, fatally injuring the very experienced pilot. The impact was very hard and knocked my wind out and when I started to focus on the surroundings, my first impression was the absolute silence and then the realisation that I was still alive. Then after all the trauma of an engine failure and a crash landing, the only strange sound I heard was what sounded like running water.... for those not familiar with the Spitfire, the only fuel tanks in the aircraft, all 76 gallons, are mounted behind the engine, separated from the pilot only by the instrument panel. The impact had caused the feeder pipe to break loose and the 'running water' sound was in fact petrol pouring out of the tank into the cockpit and over my legs.

The brain now went into overdrive, I selected the canopy release lever and grabbed the winder and cranked the canopy open; subsequent investigation indicated that with the brain in 'overdrive', getting my body to flee as fast as possible, I may have wound the handle before the catch released and snapped the cable, jamming the canopy closed. I pulled the emergency release, no luck, released my harness and chute and tried to open the side hatch, jammed too. I turned around in the cockpit on my back and tried to kick the canopy loose, still no luck, pulled the emergency handle again and this time it released, unplugged my radio cord, jumped out of the cockpit and got slammed down on the ground when the plug on my radio cord hooked around the seat up/down lever, threw my helmet off and left the scene in a hurry.

The other Spitfire passed overhead as I waved to indicate to Torr that I as all right, then I immediately pulled out my cell phone and called the Museum's Operations Officer and told him I was alright and to get the next display going to keep the crowd busy. I knew the Yak was waiting at the threshold for clearance. I then phoned the tower, no reply, probably too busy to answer the phone at that stage, can't think why. My next concern was my family as they where watching, I phoned my wife and when she answered I said "Honey I'm alright," silence, "where are you?" I asked, "on the way home to fetch a kettle". I then told her that I had crashed the Spitfire but was only slightly hurt, thought that I had broken my face up a bit as I was covered in lots of blood and maybe broken my right elbow and told her to meet me at No. 1 Military Hospital.

Still no rescue team in sight and my arm was beginning to hurt so I gave up waiting and walked to the threshold of the runway, seventy-five metres away. As I approached the threshold, the Museum Alouette II helicopter appeared which picked me up and flew off to No.1 Military Hospital. The hospital saga is also a long story, they were not informed that an aircraft accident casualty was on the way in and thus had no ambulance driver available on arrival which meant that I had to walk from the heli-pad to the emergency ward. The staff on duty were, however, exceptionally good and today none of the wound scars I received are visible. I received stitches in both knees from impact with the lower part of the instrument panel, a badly bruised right elbow, presumably from the undercarriage quadrant, a bump on the head from hitting the standby compass and a cut and bad bruising of my left cheek, courtesy of a piece of rock that penetrated the side windscreen panel when the aircraft impacted the wall. My day visor bounced up on impact, releasing the emergency clear visor which lessened the impact damage. What was the lesson here? Never fly without a helmet, visor, gloves, flying boots or a fire retardant full length flying overall.

I was discharged after a full examination, returned to the airfield to finalise the arrangements for the evening as the Museum was hosting a gala banquette for which I was the host and eventually went home and fell into a deep sleep. It was only the next day that I returned to the crash site to view the extent of the damage when I saw the wreck for the first time. I went cold just realising that this was a crash I should not have been able to walk away from, the tail had broken off on impact, the fuselage was erect but the right wing had separated and the left wing was barely still attached.

Any good safety investigator will tell you that no accident happens in isolation and there are normally a number of related incidents that lead towards the accident or warning signs that indicate a potential accident in the making. When one looks at the Spitfire accident, the indications were there, even if only very subtlety, that the engine was not running 100%, combining this with my low time on type (twelve hours) and the fact that I had not been actively flying the aircraft in the past six months, meant that I was not 100% mentally prepared to fly the aircraft.

In this particular incident, the accident was attributed to mechanical failure of the engine, nothing that could have been detected by normal servicing or inspections, however, the external environment contributed extensively towards the eventual outcome by camouflaging the warning signs.

Even to a total outsider it must be very obvious that as the Officer Commanding the Museum, Airshow director (with a brand new safety officer), display pilot and the co-ordinator for all the aspects pertaining to the airshow, my mind was not where it should have been in the days leading up to the airshow. The external pressure from the funeral arrangements, sudden changes in crew allocation and the cancellation of my solo display practice put far too much unnecessary pressure on me. There were a number of key point decisions that were made by others and myself that could have prevented the accident.

When Colonel Earle withdrew from the show, the Mustang should also have been withdrawn, I would have flown a solo practice in the Spitfire, the engine would have probably malfunctioned during the practice and since I would have not been in formation, the failure would most likely not have been as catastrophic. Without the other Spitfire in formation (there is only one thing nosier that a Spitfire, and that's two Spitfires), the subtle changes in power and engine fluctuations from the over fuelling might have been noticed sooner.

After the accident I often theorized on what if I had reacted differently to the failure, landed straight ahead into open ground strewn with boulders or elected to land with the gear up on the airfield. Had I followed one of the alternatives I would probably have inflicted as much damage to the aircraft and more to myself, I may have not been around, but whatever happened, it would most probably have been the wrong choice.

The management decisions relating to the whole confusion around the airshow also contributed to my distracted frame of mind as was quite obvious from my preflighting the wrong aircraft. The British CAA airshow regulations prohibit an airshow director from participating in an event where more than seven aircraft are involved; it is clear why this regulation exists, why not learn from other's mistakes? Why recreate the wheel?

The apparent cause of the engine failure was attributed to a combination of a slipped supercharger clutch plate and a hardened carburettor diaphragm, the more I opened up the throttle, the worse the situation became, more fuel, less air, less power ... more fuel.........17 seconds..... the time it takes to read this last paragraph!!

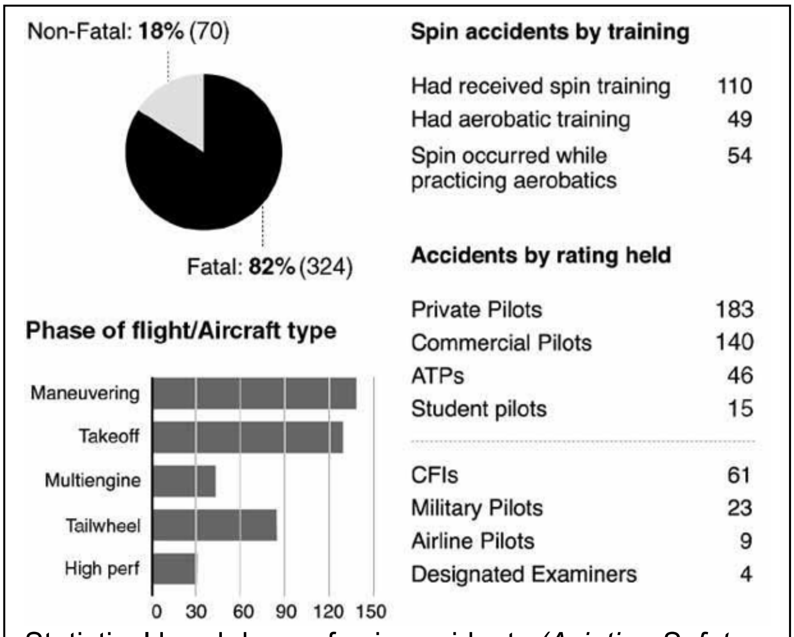
SPIN ACCIDENTS

Unfortunately, comprehensive airshow spin and even general aviation spin accidents statistics and are not readily available. In an attempt to quantify the hazards of the spin accidents, Pat Veillette launched an investigation into spin accidents, beginning with 1994 (*A Spinning Yarn* , Pat Veillette, *Aviation Safety,* May 2002). He chose 1994 as a starting point because the FAA modified stall- and spin-training requirements in 1993 and he wanted to see if the changes had made any difference in the accident record. In addition, accident reports from 1994 were fairly easy to access, while those in the preceding years were more difficult. The conclusions, although fairly general, are relevant to display and aspirant display pilots primarily because of the environment in which the spinning accidents occurred, the low-level environment being the same as for display flying there are, of course, lessons to be learnt.

There were 11,302 general aviation aircraft accidents in the six-year period studied which resulted in 2,288 fatalities. During this period, there were 394 spin accidents (3.5%) which resulted in 324 (14%) of the fatalities, illustrating the hazardous environment of low-level spinning. In this regard, the question of spin training raising its head - substantial questions remain about just how effective it is. There were more than one hundred pilots in this database who had extensive spin training, many with outstanding backgrounds but still succumbed to a spin accident. The ability to recover from a spin is often an academic argument, simply because 90% of the spin accidents occurred at altitudes that were too low for recovery. This begs the question, so what about spin training then?

Perhaps predictably, nearly 36% of all spin accidents occurred while the aircraft was in manoeuvring flight. In fact, eighty-four of the spin accidents (21%) occurred when the pilot was performing what accident investigators sometimes call “ostentatious displays at low altitude”, otherwise known as “buzzing”, “hotdogging” or “shoot-ups”. Professional display pilots know and understand that there is zero safety margin in low-level spins.

Takeoff was the next most common phase of flight for spinning accidents with 32.7% which in itself, isn’t surprising, but what was unexpected was that nearly half of the takeoff spin accidents were due to the pilot ‘showing-off’ on takeoff and using pitch and bank attitudes far in excess of safety margins. Essentially a third of all spin accidents were the result of really bad pilot judgment very close to the ground. Nearly all of these accidents occurred at less than about 300 feet AGL, so any spin recovery technique would have been useless. In fact, records indicated that a disturbing number of pilots had been spin trained, even to the point of flying competitive aerobatics. The only conclusion that can be reached is that it is not pilot skill that is in question, but pilot judgment.



Statistical breakdown of spin accidents *(Aviation Safety, May 2002).*

Roughly one-third of the takeoff stall/spins resulted from engine failures, most occurring within a few hundred feet of the ground. Twenty-four spin accidents during takeoff were partly caused by a combination of high density altitude, heavy weights, and adverse winds, all of which led to a failure of the pilot to maintain sufficient flying airspeed – a deadly combination but pilots keep stumbling on this error year after year.

Approximately 18% of spin accidents occurred during landing, slightly more than half occurred during an emergency landing but surprisingly, only one or two of the classic "turning base to final" scenarios were in the database. Most of the landing spin accidents were officially attributed to the pilot being distracted or preoccupied with a mechanical failure, followed by the pilot's failure to maintain sufficient flying speed. An important point to be made is that display pilots, outside of the display arena, revert to being just ordinary pilots and are just as susceptible to the vagaries of flight. The Spitfire crash at Rouen Valley in 2001 highlights this fact. The pilot, Martin Sargeant lost control of the aircraft on the base leg while jinking onto a runway free from spectators following engine problems.

Go-around's were the next most common phase of flight involving spin accidents, representing about 7.1% of accidents, once again, pilots not recognizing that the airspeed had decayed below an acceptable level. Cruise was the last phase of flight involving spin accidents (6.3%) mainly occurring in IMC.

In a previous study Veillette did on the altitude lost during an incipient spin and recovery, he found it took hundreds of feet to recover from an incipient spin using the optimal recovery technique. Less-than-optimal recovery technique obviously increased the altitude lost significantly. More than 90% of the spins started at such a low altitude that the spin was unrecoverable and not even the best spin pilot in the world would have recovered these aircraft prior to ground impact simply because there was simply not enough height available. This has very important implications for the stall/spin problem, from both operational and training standpoints. Obviously, pilots, and particularly display pilots, need to avoid the stall/spin boundary so close to the ground. In addition, the emphasis in training needs to be on preventing an avoiding the high angles of attack that can initiate the spin sequence, as well as proper use of rudder and aileron as the aircraft approaches the stall.

The pilot of an unlimited class YAK-54 stated he was going to demonstrate some aerobatic manoeuvres to the pilot-rated passenger. Witnesses observed the aircraft enter an inverted right spin at a lower-than-recommended altitude from which the aircraft did not recover from the spin and impacted the ground. The pilot-in-command was a general officer in the Air Force and commander of Alaskan Air Command. The general had flown more than a dozen different fighters, bombers, tankers, and experimental aircraft, including the F-117 Nighthawk, the B-1B Lancer, and the X-29. He was a command military pilot with more than 4,100 military flight hours, in addition to several thousand civilian flight hours. He held waivers from the FAA allowing him to perform low-altitude aerobatics and had competed in many civilian aerobatic competitions.

In another case, a North American T-6G began a high-g pull-up after a high-speed flyby. At the apex of the climb, the aircraft suddenly nosed over and began a slight turn left that became a hard left which developed into a snap roll and a spin to the left. After three to four turns, the aircraft struck the ground. The aircraft's POH states that the aircraft will lose 500 feet of altitude for each full spin rotation. The pilot was an International Council of Air Shows 'ACE' and zero-altitude aerobatics examiner. What the foregoing proves is that knowing how to execute a full spin recovery is rather irrelevant at such low altitudes and that there is no pilot that is not susceptible to inadvertent departure during highly dynamic manoeuvring.

Spin accidents are not the sole province of inexperienced pilots. Private pilots were involved in 46.4% of the spin accidents, and student pilots accounted for 3.8% which implies that the other half were commercial pilots, ATPs, instructors, not the neophytes one might expect. Since so many of these accidents involved low-altitude 'shoot-ups', it's obvious that pilot judgment, rather than experience level, was a primary factor in these accidents.

For many years Veillette had been staunchly 'pro-spin training'. He had been spin-trained, both in the civilian and military worlds and believed that it made him a better aviator. He had given spin training to many pilots over the years, in both powered aircraft and gliders. Fellow spin-training advocates had agreed that spin training makes a pilot more aware of the factors leading up to a spin, more capable of proficiently handling the aircraft at high angles of attack, less likely to enter into an inadvertent spin, and more likely to recover. Wrong? Maybe, but one must carefully consider that unfortunately, statistics are never able to record those spin accidents that were prevented by awareness programmes and training and thus to make firm conclusions on the exact contribution to spin prevention, is difficult. There is no doubt that spinning accident statistics, both in general aviation and also display flying would have looked significantly different without the training programmes.

That said, Veillette was shocked at the outstanding credentials of many of the spin accident pilots. The seven-year trend of data certainly cast doubt on the enthusiasm for spin training. Commercial pilots were involved in 35.5% of the spin accidents and airline transport pilots were involved in 11.7% of the spin accidents. The credentials of many of these pilots were quite impressive, some of the accident pilots were highly accomplished military pilots, some were 'fighter weapons school' instructors, some were certified by aerobatic associations, some were accomplished airshow pilots, some held 'low-altitude aerobatic waivers' and some were even aerobatic examiners. Many had graduated from flight training programmes specializing in unusual-attitude recoveries, spins, and aerobatics. In fact, many were even accomplished aerobatic or spin instructors and several were even test pilots. Even a highly experienced Reno air racer with amazing experience and credentials was involved in an unfortunate spin accident.

More than a quarter (29%) of the accidents involved pilots who had documented spin training. Although some of the spin accidents involved pilots deliberately doing spins, eighty-three involved spin-trained pilots who failed to recognize and react to an inadvertent spin in a timely manner. It can therefore be concluded that unfortunately, being spin-trained doesn't necessarily mean that the pilot will be immune from a spin accident.

Forty-nine of the accidents (12.4%) involved pilots who had aerobatic training and certification. Some of these spins occurred while practicing aerobatics, but what is of concern is that twenty-seven involved aerobatics-trained pilots who failed to recognize and recover from an inadvertent spin in a timely manner. Many of these victims had attended brand-name aerobatic schools or emergency manoeuvre training. In theory, they should have been highly capable of preventing and recovering from an incipient spin. Unfortunately, the data indicates that even being a spin instructor, doesn't guarantee the prevention of a fatal spin accident, either deliberate or inadvertent.

In another revealing statistic, twenty-three of the accidents (6.1%) involved military or former military fixed-wing pilots, this in spite of the fact that the military services having such comprehensive spin training programmes. Military spin training is supplemented by hours of classroom instruction and numerous hours are spent studying the spin section in the aircraft manual. The military programme is usually well designed for the curriculum since the most obvious spin risk in the training curriculum occurs during aerobatic practice, normally at 8,000 feet AGL and higher. Inadvertent spin entry from low-level, is a completely different matter.

Unfortunately, this in-depth and rigorous training does not necessarily transfer directly to the aircraft and spin scenarios typical of display and general aviation flying. Almost one-fifth of the spin accidents (17.5%) involved a flight instructor and it is thus evident that any pilot, regardless of experience or spin training, can fall victim to a fatal spin accident. The bottom line is one of physics. An aircraft that has departed controlled flight is operating at less than the minimum energy level required for sustained flight. To restore the energy level to sustain flight, unfortunately requires the conversion of potential energy height and at low altitudes, there is insufficient height available during low-level displays.

Trends among the aircraft involved in spin accidents are as enlightening as the profiles of the categories of pilots that crashed. One of the few rigorous scientific studies published by an independent reputable scientific society found that aircraft design was actually more responsible for the decline in stall/spin accident rates and that changes in training had little overall effect.

The "systems safety" engineering process has consistently been determined in many industries to be the most effective method for preventing accidents and injury. The application of the systems safety concept to spin accidents essentially involves as first step, that risk must be reduced, the next step is to change the design of the equipment by incorporating safety features and finally, the last step is to incorporate warning devices. Statistical evidence certainly seems to emphasise the weakness of the human in that training and procedures have been proven time and again, to be the least effective methods for preventing accidents.

More disconcerting, however, was that aerobatic aircraft were involved in forty-six spin accidents (11.7%), another area where the spin accident rate is probably disproportionate to the aircraft's use. Most of these aircraft were certified to recover from a fully developed six-turn spin. Ease of spin entry is one characteristic rather common to most aerobatic aircraft, making spin recovery training usually one of the first steps in an aerobatic training course. Nearly all of the aerobatic aircraft spin accidents involved pilots who had some level of spin training.

Spin training obviously teaches the pilot how to recover from spins, but more importantly, it helps pilots avoid inadvertent spins in the first place. The spin is the result of yaw and roll at a excessive angles of attack and avoiding the pro-spin yawing moment through proper rudder/aileron coordination, is an integral part of any attempt to solve the problem of unintentional spins. Spins that occur during aerobatic training are more realistic and representative of inadvertent spins that typically occur during actual display flights. Unfortunately, a conventional training scenario in which the spin is a planned and isolated occurrence, doesn't have the training value of a real unexpected spin.

CONCLUSIONS

I've often wondered about the validity of the "old/bold/pilots" thing. It's the kind of catchy sentiment that sounds good, so it becomes 'fact' simply because it's repeated so much. I guess there is some truth in it, as there is in most sentiments of this kind, but I wouldn't say it's in the area of a constant. Some of the best pilots I know today are old....and they were VERY bold!! The trick is to be bold at the right time.....and smart ALL of the time!!!!! (Dudley Henriques)

CHAPTER 5

THE DEMONSTRATION PILOT

A privately owned L-29 Delphin practices a low-level roll for an upcoming airshow in South Africa during 2003. (Frans Dely 'FinalImage')

He who demands everything that his aircraft can give him is a pilot; he that demands one iota more, is a fool. (Anon)

FLYING THE DEMONSTRATION

Display flying essentially involves manoeuvring the aircraft in view of a group of spectators and may, or may not, involve aerobatics. Webster's new 20th-Century Dictionary of the English Language defines aerobatics as: 1. *Spectacular feats done in flying as loops, rolls, etc* . 2. *The art of doing such feats in flying* . The legal definition given by the Federal Aviation Regulations Part 91.303 is: "An intentional manoeuvre involving an abrupt change in an aircraft's attitude, an abnormal attitude, or abnormal acceleration, not necessary for normal flight".

Whatever the definition, however, watching a pilot die at an airshow during a crash, the question commonly asked is: "Aircraft are made so very well and pilots so well trained, why and how does this have to happen?" Reading through accident investigation reports it is difficult to find a case in which an inexperienced pilot was involved in a display accident; on average, they all seem to have in excess of 3,000 flying hours, one as many as 24,000 hours, all 'old-hands' in flying and in most cases, 'old-hands' in the display world. The airshow world is relatively well regulated and in most cases, the criteria to qualify as a demonstration pilot, by its very nature, requires that a pilot has a certain minimum number of flying hours before being authorised to fly at airshows.

What this does tell us is that display flying, as in all categories of flying, has no respect for experience, only practiced skill and discipline and even then, there is a fine line between success and failure. So what goes on in the mind and psyche of the pilot? What are the stressors that affect reaction times and decision-making? What does the pilot experience physically and mentally while manoeuvring an aircraft in a confined volume so close to the ground? What is the pilot workload and stress level? How important is concentration?

To attempt to answer some of these questions, Dudley A. Henriques, International Fighter Pilots Fellowship, sums it up neatly. "Let me put you in the cockpit of a P-51 during a display if I may, and perhaps I can help put these questions into some kind of perspective. I'll only take one type of manoeuvre to illustrate; it could be an inside loop, a half-Cuban, or reverse half-Cuban turnaround. I'll use an inside loop as an example. The main thing here is that these manoeuvres involve a vertical recovery at very low altitude and they have killed many of us who perform them. The situation I will describe here is for the P-51 Mustang as I used it, but the basic aspects involved pertain to any pilot and aircraft in this environment. Only the engine settings and control forces will vary from aircraft to aircraft. I want to give you some idea of the tasking and concentration involved with this work.

Entering the show site after exiting the last manoeuvre in the sequence, you line up diving in at METO power [46" and 2700RPM]. You already have the show centre point and are now concentrating on the show-to-crowd restriction line, which is displaced 1,500 feet in front and parallel to the crowd on your left. You are using the runway centreline in this instance for spacing. The entry speed for this manoeuvre, an inside loop, is exactly 350 mph. This is critical since the 'g' profile you will use, a gradual pull to 4g, must be exactly married to the IAS and the entry altitude to put you on the top of the loop at your 'go/no-go' decision height. This decision point or 'energy gate', is also commonly referred to as the 'commit point' for the decision to continue with the pull to the visual sight cue for the second half of the loop and exit.

You reach pull point with all the parameters married and commit the airplane to the manoeuvre with a smooth pull into a rising 'g'. From here on it's 'feeling' and 'listening' to the airplane. It's how you mentally assess what the airplane is telling you that matters here, not the math of aerodynamics, lift, drag, and the rest of it. Oh it's all there all right, but you don't have time to think about it.

Your 'feel' of the airplane will determine how the figures end up at the top and bottom of this manoeuvre. There will only be one chance at the recovery. Wrong is dead! As the 'g' builds, you transfer your visual cue to the left wingtip, feeling the 'g', and ‘adjusting’ it as the aircraft goes vertical. Now is where the torque changes hit you, you can feel it on the rudder. As the energy bleeds through the ‘g’ profile, that huge Hamilton propeller up front begins to want to turn the airplane off the vertical line. It requires more and more right rudder to hold the wingtip on the horizon line. Now you’re past 90º into the manoeuvre. You shoot a glance at the altimeter and ASI for profile confirmation and make a slight adjustment to unload the airplane just a touch because your mind has projected the manoeuvre line below your target altitude at the top if you don’t ease up on the pull, based on the angle of the tip to the horizon and the rate of the altimeter needle toward the target at the top. A quick glance at the slip-ball confirms torque correction is on line. As the aircraft inverts at the top, you have a major decision to make. There is no book written that will explain it.

Remember, you have split seconds to assess and decide. Right, the manoeuvre is continued to a beautiful finish at the bottom. Wrong is not a survivable option past 270º in the recovery. You shoot a lightning glance at the altimeter; make a slight alignment of the inverted horizon to straighten the wings. You digest the sight picture, mentally doing the geometry from the horizon line through the amount of ground showing in the windshield. You make a lightning check of the ASI for parameters and you DECIDE!!!

You pull to a vertical downline commit based on these visual cues and experience. You have until you go vertical at 270º to change your mind and initiate a ‘rollout’ save. Once at 270º, the shortest route out is the vertical pull. The real commit is at that point! You pull the power back a bit and begin the recovery. You have split seconds to make the final decision between inverted and the 270º point. At 270º, the sight picture tells you to commit and you do so. You are now either alive or dead, based on this decision. The only asset you have to play off against remaining altitude is the remaining radial ‘g’. If you don’t have enough radial ‘g’ between you and the ground, it’s all over but for the tears and sorrow!

A lot of pilots don’t know this, but if the loop is flown correctly, a vertical recovery like this is actually done by releasing some of the back pressure during the last twenty degrees of the dive recovery instead of holding in the back pressure you might be visualizing for a loop recovery. What should happen is that you reach a point in the recovery at about 340º where you can ‘see’ and ‘feel’ that you have the height and ‘g’ married correctly and that the airplane has the room to make the recovery before you will hit the ground. At that point, the ‘good pilot’ will relax the backpressure, flattening out the dive recovery somewhat, and allow the propeller tips to ‘trim the tall grass’. This of course precludes you having allowed yourself the room to do this.

The time to begin worrying is that exact point where you realize you will need continuing backpressure to complete the manoeuvre. The amount of that backpressure will determine whether or not you recover, reach C_{Lmax}, or the ground first. Only ‘recover’ will save you. The other two have already killed you! The point of telling you all this is simply to give you some idea of what can happen to a pilot flying an airshow. You can imagine that mechanical failure is always an option as well. Even if you’re good, it only takes one second’s lapse of concentration to kill you in this environment. You practice and practice harder to make yourself better at this. Even then, it can bite you. It just happens that danger is a part of the show equation, I loved doing it. I was a fair stick if I may say so, better than some, and not as good as others I knew and know today. I survived the decision I have described above many, many times. I’ve watched others who didn’t”.

What is intriguing is that display pilots, by the very nature of the safety demands enforced by the airshow world, are generally very experienced pilots. The fear factor in most pilots makes them realise the hazards and they thus elect to enter this hazardous arena only once they have the experience and confidence. Aviation accident archives are full of records of inexperienced pilots, military and civilian, that have killed themselves doing ‘unauthorised’ low-level aerobatics. What is it then that seduces the mind of the experienced display pilot into making, what in retrospect are poor 'commit decisions' or courses of action that invariably result in the pilot's own death?

THE SEDUCTION OF THE PILOT PSYCHE

Frank C. Sanders, a test pilot and a veteran airshow pilot with twenty-four years experience had been interested in a specific accident of an F/A-18 on 24 April 1988 at the MCAS El Toro (USA) airshow since the day he had watched it broadcast on TV. He waited for the pilot to recover sufficiently from his injuries to enable him to assist in researching the physiological aspects of the accident and wrote a research paper to expand on the finding of "Pilot Error" by the accident board. The finding of "Pilot Error" is an all too familiar 'easy out' for accident board investigations, no specific details, just the 'old cliché', "Pilot Error". It has to be emphasised that no pilot willingly causes an accident or gets himself killed during an airshow. Onthe contrary, the adrenalin charge generated by the body is a result of the pilot's obsession to stay alive.

However, the weakness in the physiological make-up of all pilots makes it impossible for them to guarantee flawless judgement and flying skills. With this in mind, Sanders quite rightly maintained that: "if we can understand the causal factors and mechanism of the term 'Loss of Situational Awareness', then possibly, we have taken the first step in educating display pilots to avoid this hazard." As in most accidents there is usually more than one contributory cause that leads to the eventual accident, a similar analogy to the 'domino principle'. The aim of the research paper was to shed some light on a complex subject and in the process, increase safety for all display pilots.

As background it is prudent to consider an article published in the 8 May 1989 issue of *Aviation Week* on the "Peripheral Vision Display (PVD)" artificial horizon. This article quoted Richard Malcolm at Canada's Defence and Civil Institute of Environmental Medicine: "Of the senses, vision contributes about 90% to human orientation and balance, and the inner ear only about 10%. The majority (90%) of visual orientation is contributed by peripheral vision."

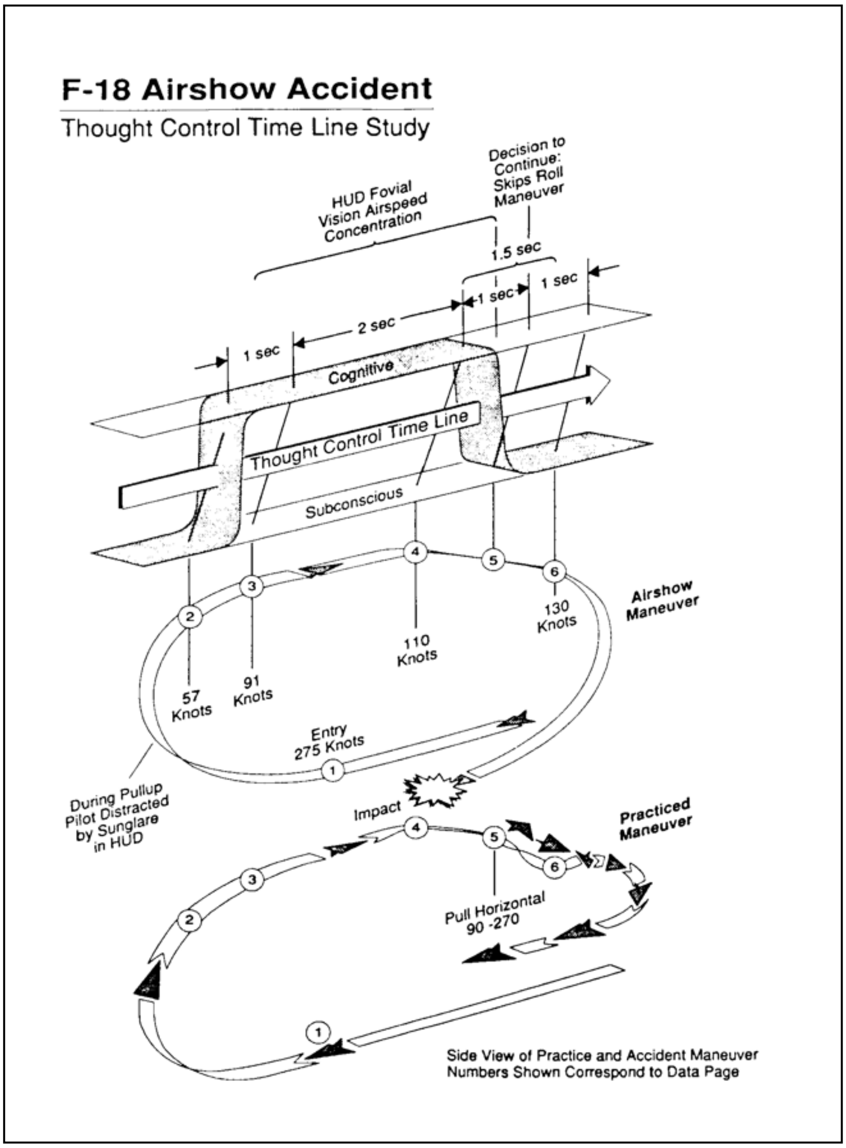
This information, added to the research Sanders had done relating to adrenaline and loss of peripheral vision to the cognitive mind, suggested a new approach to reviewing the Heads-Up-Display (HUD) tapes of the F/A 18 accident and comparing it with the two HUD video tapes of Col Jerry Cadick's two practice flights prior to the accident.

When Sanders learned that the 'square loop' that appeared on TV was not the planned or practiced manoeuvre, the question of what happened became much more intriguing. As a point of fact, the desired manoeuvre was the 'Pitch Rate Demo'. In airshow terms, a square Immelman with a descending 90º - 270º horizontal reposition for the next manoeuvre. Why, or even better, how could this become the square loop that resulted in the accident?

Studying the video taken from the vantage point of the air traffic control tower, Sanders saw no indication of problems in the first series of manoeuvres. Some accidents have a gradual deteriorating performance, a transitional regression that is obvious prior to the accident. But the undercarriage-down Immelman flown by Colonel Cadick just two manoeuvres previous to and similar to the accident manoeuvre, was flown with precision and a perfect recovery – a crisp roll to the repositioning 90º - 270º turnaround.

Before Sanders undertook the study, he first had to verify in his own mind whether the pilot was average or inconsistent or, perhaps, unqualified to do that type of flight in the F/A-18. The conclusions that he proposed in the research paper were the result of having satisfied himself that this officer was a superior aviator and was adequately prepared to fly that airshow. As a matter of information, Sanders had personally flown with Col Cadick on two occasions, these were Cadick's first two flights after the accident and in Sander's opinion, Cadick was a talented aviator. Therefore, it was accepted at that point that there was a serviceable aircraft and a pilot that was competent, practiced and functioning well. He had approximately 1,000 hours on the Hornet and had been an instructor on the F/A-18 for 3 years and 7 months and had flown it every month since September 1982. His only exposure to aircraft accidents prior to this mishap was a deadstick landing on a T-33 in a cornfield in Ohio and a deadstick landing of a TA-4F at MCAS Beaufort, South Carolina, both the result of mechanical failures.

This aviator, as most airshow pilots are, was concerned about the amount of time taken for the repositioning manoeuvres and an attempt was made to reduce the turnaround time spent away from the crowd. Entry speed and altitude was relatively consistent on each of the three days with 275kts the target speed (290 kts/490 ft, 268 kts/520 ft, 275 kts/490 ft) but, unlike previous days, the engines were at approximately 80% on the day of the accident when the afterburners were selected. In the F/A-18, the afterburners do not light-up until the engines are at or greater than 92%. This would account for why the burners only lit after the aircraft had pulled to the vertical, resulting in less displayed airspeed and altitude at the top (111 kts/2800 ft, 92 kts/2380 ft, 57 kts/2180 ft). In each practice the burner selection was made at the same point, but less airspeed and less altitude was achieved at the top of the square Immelman than the previous time. To Frank Sanders, the question was: "How did pilot error, or more correctly, 'Human Factors', cause Col Cadick to get the nose so low, approximately 80º nose-down when he recognised that from that situation, the only option left was to pull through the vertical and complete the manoeuvre as a loop? A manoeuvre that he had neither planned, nor practiced.



At this point, the first step at better understanding the problem is to know how the brain works and how the display pilots make the decisions they make. The brain is incredibly complex, but the reader attention focus should be on the "conscious" and "subconscious" part of the mind. Scientists recognise thought, feelings and sensation as the stuff of consciousness, and the chief guardian of consciousness is located in a cluster of nerve cells known as the reticular formation. The reticular formation is, in essence, the brain's chief gatekeeper.

Every second, 100 million messages bombard the brain carrying input from the body's senses. A few hundred are permitted through to brain regions above the brain stem. Of these, the conscious mind heeds fewer still and concentration is limited to one sensation at a time. Now, the reason we practice any complex task (typing, bicycling, flying, etc) is that repetition allows the subconscious brain to assume control of the task; the task that the first time performed, had to all be done on the conscious (cognitive) level. The subconscious brain can handle multiple tasks with practiced ease as long as proficiency is maintained; adrenaline seems to have little effect on this capability of the brain. The limiting factor is the cognitive part of the brain. In our conscious mind, we can concentrate on only one problem at a time and we have to time-share if more than one at a time is to be worked. Remember TIME SHARE! Only two or three items can be time shared by this cognitive brain, depending on complexity and adrenaline; yes, adrenaline affects the cognitive brain function. One very dramatic way to cut down on time-sharing is to block our peripheral vision and only perceive with foveal vision.

Foveal vision is the 3º cone of focussed vision that we read with. This is pointed out because peripheral and foveal vision is particularly germane in Col Cadick's mishap. There may be a unique occasion when the conscious mind, by virtue of the reticular activating system, perceives at least some of the sensory input that the subconscious mind looks at all the time. During a sudden emergency or shocking event, the conscious mind may even perceive the event happening in slow motion, remembering things later with amazing clarity. This may be the conscious mind looking to the subconscious for information or monitoring its function without inhibiting it.

What happened? What cognitive items does the proficient display pilot concentrate on? A mental rehearsal prior to take-off of the planned show sequence and known adjustments reduces the amount of cognitive time needed on flying the sequence. The large time-share items are adjustments for clouds, wind, crowd-line and energy management (airspeed and altitude). Flying the aircraft (stick and rudder) is done by the practiced subconscious. Energy management is a cross-check of predicted airspeed and altitude conditions; the total energy of the aircraft being the summation of potential energy (altitude) and kinetic energy (airspeed). If the total energy starts to decrease, the pilot must either add power or reduce drag by flying a wider show (less 'g' induced drag).

Point	Event	Practice 21 April	Practice 22 April	Accident 24 April
1	Airspeed & Altitude at Pull-up	290 kts/ 490 ft	268 kts/ 520 ft	275 kts/ 490 ft
2	Lowest Indicated Airspeed/Max AOA	111 kts/ 42º	92 kts/ 44º	57 kts/ 48º
3	Level Inverted Airspeed	122 kts	97 kts	91 kts
	Airspeed Error	11 kts	5 kts	34 kts
	Altitude on Top	2800 ft	2380 ft	2180 ft
	Horizon Display	-3º	-7º	-7º
	Altitude Lost	20 ft	30 ft	30 ft
	Accel Rate (neg g)	10 kt/sec^2	10 kt/sec^2	10 kt/sec^2
4	Airspeed	130 kts	120 kts	100 kts
	Pitch Rate	5º/sec	7º/sec	7º/sec
	Accel Rate (zero g)	20 kt/sec^2	20 kt/sec^2	20 kt/sec^2
	Time to Roll	1.0 sec	1.0 sec	No Roll
	Time to Pull	0	0	1.5 secs
5	Speed at Roll	150 kts	150 kts	155 kts
6	Pitch Angle	-	-	-17º
	Pitch Angle (+1sec)	-	-	-35º
	Slice Turn Angle	-35º	-40º	-

The reason for cognitive attention is that the ratio of energies may change although the total energy remains constant, and therein lies the hazard. Too fast and too low at the apex of an over-the-top manoeuvre and the recovery radius is too large to miss the ground. This energy ratio changes with density altitude and always requires cognitive attention. According to Sanders: "I did not fully appreciate 'The Cobra in the Basket' when Dave Barnes (Northrop F-20) described his fear of focussing on a piece of glass, the Heads-Up Display (HUD) eighteen inches in front of his face and not seeing where his 500 knots jet was going. Dave believed that a trap existed in not looking around or through the HUD. Coincidentally, in an unrelated type of accident, Dave Barnes was subsequently killed on 14 May 1985 during a display practice while flying the Northrop F-20 Tigershark at Goose Bay, Canada. Frank Sanders had a theory that the combination of very high roll rates and high 'g' available in the F-20 could make a pilot particularly susceptible to disorientation and/or GLOC (g-induced loss of consciousness, not to be confused with an ordinary g-induced blackout).

For those who have never used a HUD, the HUD is essentially a transparent collimated glass display through which the pilot, focussing at infinity, has the essential flight information of airspeed, altitude, navigation and weapons information displayed. Displaying such essential flight parameters through the HUD, induces the pilot to fly the aircraft through the HUD picture. Unfortunately reflections from the sun in the near vertical midday or early morning/late afternoon sun position may cause the HUD picture to 'wash-out' making it impossible for the pilot to see what symbology is displayed on the HUD.

But the HUD video provided an amazing insight into just what Col Cadick saw and did not see when the sun 'washed' it out on the accident day. Sun glare is particularly distracting, especially in the earlier generation HUD technology and the only option available to the pilot is to continue with the manoeuvre knowing that the phenomenon is transient, normally lasting only a few seconds until the relative angular relationship with the sun changes. A frame-by-frame analysis of the HUD video provided a data review page is illustrated in Fig. 1 that sets up comparisons of critical performance parameters for each practice day and then the airshow. For clarity, Fig. 2 graphically portrays this information in a side view of the manoeuvre. On the accident day, the lower altitude at the top of the Immelman (200 ft less than the previous practice) is not a major concern if you are not going to pull through vertical, but the dramatically lower airspeed is a problem if you roll. After all, the aircraft does need adequate airspeed in order to roll without excessive height loss and control of the pitch attitude.

Analysing the data on the graph reveals a very consistent pilot. For example, the altitude on top inverted (Point No. 3) and the inverted altitude at the roll (Point No. 4) never varies more than 30 ft on three flights. The duration of the inverted flight segment was within 0.5 seconds on each day while the airspeed at the end of the inverted flight segment was within 30 kts on all three days. "As an airshow pilot, I believe this data indicates enough practice and comfort with the manoeuvres. Why then is there no roll at the end of the inverted flight on the accident day?" Sanders questioned. Before answering, it is prudent to note that pilots of computerised flight control systems pay greater attention to indicated airspeed because there is no tactile feel, no stick feedback cues as airspeed increases or "wind over the wires" to provide a feel for energy state. On the accident day, due to the aircraft pointing into the sun, the HUD symbology 'washed-out' and when the airspeed eventually became visible in the HUD, the initial reading of 65 kts decreased to 57 kts at 10° above the horizon coming over the top inverted at 48° angle of attack (AOA).

After careful comparison, it can be seen that the aircraft was in actual fact, only 10 kts slower than the previous day's practice when the nose came through level inverted on the horizon. For accident analysis purposes, this 57 kts indicated airspeed provided an excellent clue as to where the pilot's attention was focussed at that point. It took Sanders several days to realise that the 57 KIAS was an error because the aircraft thereafter accelerated to 91 KIAS in one second while it was nose-high indicating 48º AOA with the aircraft still climbing. Impossible of course! Acceleration for the next two seconds was 10 kts/sec [2]. How did this, now obviously incorrect airspeed, come to be displayed? Because of Pitot tube pressure inaccuracies at AOA greater than 33.1º, the IAS is corrected by the inertial navigation system. As a result, IAS is sometimes inaccurate, particularly in highly dynamic flight conditions. At the point the 57 kts was displayed, the actual airspeed must have been approximately 110 kts - an error in excess of 50 kts!!! As the 91 kts appeared in the HUD display, the pilot was busy (cognitive time-share) putting the nose level on the horizon and the decision to extend for airspeed had already been made. But the next time the airspeed was checked, it was only 10 kts slower than practiced. This confusion caused more distraction and more time was devoted to the HUD airspeed indicator.

As the parameters returned to normal, the cognitive brain directed the practiced subconscious to continue the manoeuvre as practiced. HERE IS THE INSTANT THAT THE ERROR OCCURRED!! An error of omission that has its roots in the function of the human brain. Because of the extra filtration of information to the cognitive mind (remember the gatekeeper) and the delay caused by timesharing, the conscious mind operates with a slight time lag compared to the practiced subconscious. The practiced subconscious can handle more input information and operates much quicker. Naturally, this is a very complex subject, however, Sanders developed a simple timeline and applied it to the HUD video data to illustrate the relationship between the two. Note that the Thought Control Time Line represents Sander's analysis of the shift in brain focus between the subconscious and the conscious mind.

In Sander's opinion, Col Cadick, alarmed at the 57 kts HUD airspeed, cognitively interrupted the manoeuvre until he was satisfied that he had regained flying speed. This was a rational and correct technique to adopt given the information available to the pilot at that particular moment. However, because of the slight time difference between the conscious and the subconscious, when control was again passed to the lower line, the practiced subconscious was one step ahead timewise in the programme – just past the roll, and to the pull 90º horizontal. Thus there is a pull of approximately 80º nose-down, not horizontal as practiced! The perceived airspeed error was an unpracticed interruption to the practiced subconscious skill programme. Note that this was the only flight of the three days with such a large discrepancy in indicated airspeed. This time base error experienced was HUD related.

Peripheral vision that is used to orientate or to keep the two levels of the brain in step with each other, was no longer functioning. Foveal vision was in use. Peripheral vision that we use to fly with on the subconscious level of the brain, was overridden by the cognitive mind functioning on foveal vision. Remember that 90% of our orientation is from peripheral vision. What would cause an extremely experienced F/A-18 pilot to lock out this vision? Remember Dave Barnes' Cobra in the Basket (the HUD) with its beautiful digital airspeed and altitude display that required foveal vision to read. Call it tunnel vision, target fixation of foveal vision/cognitive mind information lockout, the result is the same - the pilot does not get the peripheral vision information needed. This helps understand the error of omission; when with the proper information, a critical step in the performance was omitted. Hence "pilot error". The point that most guarantees that this was an error of omission, was that the roll was left out of the sequence, is Point No. 4 on the graphic illustration.

On all three days the forward pressure on the control stick to fly inverted, is released to positive 'g' and the nose goes 10º below the horizon and pauses in preparation to roll. If the intended manoeuvre on the accident day had been a square loop, as some believe, the inverted flight would have gone directly to the square corner down. It took Sanders several days of frame-by-frame analysis of the

HUD video in order to see this and he firmly believed that the result of this examination is the proof that his reasoning, as described, explaining why this pilot pulled vertical instead of horizontal, is correct.

The bottom line is this. Sanders saw a square loop on TV that day, and so did most pilots. An experienced display pilot who witnessed the accident gave his opinion as: "The driver got behind his programmed manoeuvre, what looked like a square loop. He 'greyed – out' pulling down for the back side of the box, got his eyes back, saw he was getting too low, and did the stick in the stomach routine. From the video footage, he damn near pulled it off, his rate of descent was very low at impact, but the tail dragged and slapped the nose down."

However, remember that the 90-270º turn was now erroneously orientated in the vertical axis. The pull down was unhurried as it was practiced in the horizontal and the pull rate relaxes, as it should, to roll left for the reverse to the 270º turn. At this point, the cognitive brain has again looked outside the HUD with peripheral vision and discovered to its horror that the aircraft was nearing vertical down. At this point, a hard pull was initiated to minimize the impact, hence hesitation in recovery that gave the square loop the spectators saw.

The unique aspect about this accident was the availability of the three days of recorded HUD video information to analyse and to compare the human performance. Without this information, an understanding of this accident would have been impossible. The message for the display pilots is: don't lose peripheral vision in a high stress situation. More than just losing spatial orientation, range and rate of motion in depth, peripheral vision keeps areas of the brain indexed in time to perform complex tasks. The good news is that the cognitive has the authority to command to see peripheral vision. The bad news is that it requires foveal vision to perceive digital information. Display pilots must ensure, therefore, that peripheral vision is included in their scan pattern of airspeed, altitude and attitude.

In summary therefore, the lower engine RPM at the beginning of the manoeuvre was the beginning of the problem. The 'domino effect' produced a lower airspeed reading on top of the manoeuvre than had been practiced. The pilot had retrograde amnesia after the accident, but could later recall some portions of the events leading up to the mishap. Col Cadick remembered that he knew the airspeed was going to be slow on top because of late afterburner engagement, however, the 57 KIAS was much slower than anticipated and the following chain of events began:

- The cognitive decision to extend for airspeed caused an unpracticed interruption of practiced subconscious programme.
- Confusion due to an impossible acceleration rate (57 – 91 kts in 1 second) required cognitive time to resolve problem airspeed.
- Foveal vision concentrating on digital airspeed required cognitive attention until satisfied with airspeed, and negative 'g' relaxed in preparation to roll.
- Due to foveal vision, when the cognitive mind returned control to practiced subconscious with roll yet to come, they were not time synchronised.
- The practiced subconscious was one step ahead of the cognitive mind in the sequence; just beyond roll, therefore, the pull for the 90º-270º turn was erroneously oriented in the vertical.
- As peripheral vision returned, the cognitive mind comprehended the situation and commanded a hard pull in an effort to minimize impact.

Because this was an unpractised interruption of the subconscious programme, an error of omission occurred where a critical section of a manoeuvre was left out, not an intentional square loop that appeared to the uninformed observer.

This airshow accident demonstrated a classic case of some of the reasons the brain filters out peripheral vision and how deadly important peripheral is to maintaining situational awareness. If it could happen to a pilot who was experienced, capable, and practiced, what is the next step? Nobody is going to change the way GOD designed man to function. Accordingly, Sanders' recommendation was that: "we ought to get busy and educate our HUD pilots on the limitation of the interface. The HUD is good but it is no guarantee in and of itself that situational awareness will always be maintained. Further, he believed that in the light of this accident, a fresh look be taken at the ergonomics of future designs of visor-mounted sights and other space science systems. A better understanding of how we, the human pilot functions, can influence the design". ("The Cobra in the Basket: What You Don't See Can Kill You" - Frank C. Sanders - SETP)

In what can be described as justification of Sander's investigative work on airshow accidents, particularly relevant to the case of Hood's, the latest HUD technology has advanced dramatically and the safety recommendations of the past are incorporated in the Holographic Wide Angle Heads-Up-Displays fitted to fourth generation fighters.

This example is just one of the many that demonstrates typically why pilots can be seduced into poor decision-making. Once the decision has been made, it is irreversible – if the decision is wrong, the pilot is a passenger at an accident unless of course, there is the availability of a capable ejection seat, but even then, survival is not guaranteed. The problem is that due to the highly dynamic environment and the high energy levels associated with manoeuvring aircraft, there is zero error margin.

DISPLAY PILOT CHALLENGES

The human is not a robot but has emotions, an ego, and the desire to compete, including a fair amount of aggression – that is how we are put together – it is not something that can be put aside or ignored. But aggression and ego without fear is a dangerous combination, aggression without understanding one's personal capabilities and the limits of the aircraft, is downright dangerous.

What makes a highly experienced display pilot decide to continue a series of low level aileron rolls once the nose begins to fall? What makes a pilot continue with a loop, reaching the top 'out of parameters', low airspeed or low altitude? What makes a pilot suddenly decide to increase the airspeed of the manoeuvre by twenty knots more than that practiced? What makes a pilot 'press' the height and speed to the limit during a flypast? Well, most pilots know the feeling of being able to select full throttle, feel the acceleration and then try to 'squeeze' it as low as possible – it is a feeling of freedom and power to impress the spectators – but it is also the door to disaster if such emotions are not channelled. Provide an answer to the foregoing questions and the hazards of low-level display flying will be better understood and airshow accidents considerably reduced.

Ironically, experience unfortunately removes many unknowns for the display pilot, breeds confidence and even over-confidence in some cases. In contrast however, but even more unfortunate, is that display piloting skills, response and reaction times, can never be perfectly honed to guarantee 'zero error'. Competition then, also often brings out the worst in the human being, the element of winning at all costs combined with the requirement by airshow spectators for greater entertainment value from the airshows, provides all the ingredients for an airshow accident unless all these energies are sensibly channelled.

On a video clip of John Derry's fatal accident at Farnborough Airshow in 1952, Capt. Eric 'Winkle' Brown (world renowned British test pilot), questioningly expressed an opinion: "John Derry was far from being an irresponsible pilot, but I know the feeling well.....that when you are at an airshow, there are pressures on you to be competitive with the other pilots. Its the top people in the business being thrown into the gladiatorial ring and all wanting to show off their company's wares to the best of their abilities, and it is just possible that John pushed it a fraction more.......that is the difference between success and disaster". Stated almost fifty years ago, the question must be asked: "have we learnt any lessons yet or not? Well, in some cases yes, but in others, not!

So, what is the extent of the problem actually? Well, the definition of the problem is simple, the solution to the problem is, however, far more complex. In fact, it is doubtful that it can be completely solved because of the human's fallibility in judgement and anticipation under the pressure of dynamic manoeuvring – at best, accidents can only be alleviated by absolute knowledge, discipline and practice. The problem that has been acknowledged since man's first flight is that the low-level display arena, for a manoeuvring aircraft, is one of the most demanding and intimidating environments for the pilot to operate in.

Over the years, the improved aerodynamic design, increased mass, increased performance, increased power and increased agility of aircraft, has changed the focus on the causal factors of the accidents somewhat. With increased performance and agility, pilots have designed demonstration sequences that have attempted to emphasise and demonstrate such dynamic features. However, high inertial moments, high momentum and then also high closing speeds in excess of 1,200 feet per second, all critically affect the pilot's reaction and response times. The tolerance for error has shrunk to extremely small values, the scope for human error is now considerably small and consequently, the probability for judgement error has, in most cases, increased.

Modern high performance fighter aircraft are imbued with high thrust-to-weight ratios and very good rolling performance, capable of generating in excess of 360º/second in some cases. The handling skills required by a pilot in displaying rolling manoeuvres in a modern fighter is therefore less than in the older vintage earlier generation warbirds that can typically generate maximum roll rates of only 120º/second. What this simply means is that for the earlier generation aircraft, low-level rolling manoeuvres require greater skill in handling and co-ordination than in a modern high performance fighter. Add to this the fact that the rolling trajectory of a modern aircraft more closely approximates the inertial axis of the aircraft, this makes it easier to display multiple aileron rolls. In the case of early generation aircraft, however, the aerodynamic axis and the inertial axis are not necessarily so closely aligned and the straight roll invariably approximates a tight barrel-roll or corkscrew trajectory.

A factor not to be forgotten when discussing rolling vintage aircraft is the adverse aileron yaw and engine torque inherent in the vintage aircraft designs which can significantly reduce roll performance. The approximately 2,400 horsepower developed by the Hawker Sea-Fury's engine was a real handful, even for the experienced operational pilots, current on type – high engine power settings at low speeds could make 'your eyes water' if not flown correctly since the rudder authority at such low airspeeds is inadequate to prevent a torque roll. The skill required of the pilot flying such high performance piston aircraft is only acquired through many hours of practice, practice on the specific type, not a similar type unless the power-to-weight and torque values are similar.

One of the problems facing vintage aircraft flying of course, is that the owners invariably have sufficient finances to purchase such aircraft, but more as a hobby than a professional occupation. Such owners may not necessarily be sufficiently experienced or trained to handle the power and its associated roll/yaw moments in the dynamic flight display arena in which low speeds are common. Any error in judgement is amplified, further reducing the margin for error in this hostile environment.

The accident that killed airshow pilot Carey Moore on 9 July 2001 when his Hawker Sea Fury crashed while performing at the Sarnia International Airshow in Sarnia, Canada, typifies the corner into which a display pilot, irrespective of experience, can get into. Eyewitnesses reported seeing the aircraft in a steep turn just before the aircraft pitched nose-down and hit the ground. The aircraft reportedly entered an incipient spin after doing a climbing turn from a slow, low-level pass. Other examples of this hazard, more particularly excessive nose-drop below the horizon due to poor pilot technique or error of judgement are plentiful. In the case of the early vintage aircraft at airshows, consider the A-20 Havoc at Biggin Hill (UK) in 1980, the Bf-108 'Taifun' at Berlin in 1995, the P-38 Lightning at Duxford (UK) in 1996 and the AT-6 Harvard at Lafayette (USA), in 1996. In all reports, witnesses described the final 180 degrees of the final roll as a 'scoop'.

The aforementioned examples serve in a small way to illustrate the hazards of low-level display flying. It is evident that to improve safety margins in an environment that is intolerant of errors, the only way for the pilot to survive is through continuous practice to overcome the deficiencies in judgement and anticipation that make the human the weakest link in the display flying safety chain.

Even the most modern fighters are challenging to display safely, perhaps the biggest challenge for pilots demonstrating the latest fourth generation fighters such as Gripen, Eurofighter and F-22 is managing the excessive 'thrust-to-weight' ratios, which in most cases, are in excess of 1:1. The relatively slow human response and reaction time, coupled to the relatively low physiological tolerance of the human, is incapable of fully utilising the potential performance of the aircraft. The pilot workload now has to focus on managing not only the display sequence, but also the 'staggering' energy levels and consequent accelerations that are capable of being generated about all three axes.

For example, at Farnborough 2000, after a take-off roll of only 750 metres, Eurofighter was accelerating at 30 kts/second and at such a high T/W ratio, enabled the aircraft enter straight into a loop from take-off with the fighter still accelerating rapidly through the vertical. From the loop after take-off, the aircraft entered a slow but tight 360º turn at 115 KIAS and exited at 180 KIAS straight into another rapid acceleration loop. According to the BAE Systems test and demonstration pilot Keith Hartley: "The major challenge is to control the airspeed while remaining within the display box". It helps that the aircraft is now 'fuelled-up' and not 'fuelled down' being flown with 60% fuel load instead of the minimum fuel airshow weight". Never before in the history of aviation and particularly display flying, has the pilot had the luxury of 'too much excess power'.

"The Eurofighter routine is easy to fly, the flight control system providing carefree handling features that won't let the pilot stall the aircraft or pull too much 'g' at varying angles of attack. But that makes speed management even more crucial to remain within Eurofighter's display area. For example, even while pulling 7g in a 360º turn steep turn, the aircraft is still accelerating with full aft stick", Hartley said. The airshow routine used by Eurofighter is designed to focus the demonstration on its ability to accelerate, especially in the vertical and to manoeuvre in confined volumes. The huge incremental step in aircraft performance has of necessity, transformed the concept of energy management.

However, increased performance and agility is not only a feature of modern fighters but is now also a design feature of modern sport aircraft. The Edge 540 utilizes a computer optimised steel tube fuselage with a number of unique features that results in a stronger, lighter fuselage designed to absorb over 15 g's of sustained loading. The 327 HP engined Edge-540, at an aerobatic maximum gross weight of 1,550 lbs, also has the highest aerobatic power-to-weight ratio of any competition aerobatic aircraft currently available and is also capable of generating roll rates approaching 420º/second.

For the highly manoeuvrable high performance jet, however, the most critical hazard arises not in the rolling plane, but in the vertical plane. Excessively low or excessively high total energy levels at the top or approaching the bottom of vertical manoeuvres can result in impact with the ground if the manoeuvre is continued and not converted into an escape manoeuvre.

A more recent challenge to display pilots which contributes to the hazards of display flying is the phenomenon called "G-LOC", or g-induced loss of consciousness; a direct spin-off of the increased aerodynamic agility induced through modern design. Pilots and display pilots of earlier generations of fighter aircraft would often experience 'grey-outs', 'red-outs' or even 'blackouts'. This G-LOC phenomenon is relatively new to flight physiology and, contrary to the mechanism of 'blackout' caused by high g values, has its origin in the 'rate of g onset', not maximum g and poses a serious hazard to displaying highly agile aircraft.

Modern fighters have been designed with negative static margins making the aircraft essentially unstable, their stability and control being achieved through computers via fly-by-wire signals from the pilot. The stability system is "artificial" or apparent and the fly-by-wire system implies that there is no direct mechanical connection between the control stick and the control surfaces. The onboard-computers interact with the electronic signals from the stick, offering automatic levelling, smoother manoeuvres, higher agility, etc. Since the aircraft is essentially unstable and needs the computer to even stay in the air. In modern fighters, agility remains a critical survival criterion and design engineers have continuously tried to maximize this capability. The agility of the latest generation of aircraft is thus considerably increased over conventionally controlled aircraft but the problem is that the human physiology has not yet been improved to match and keep pace with modern flight control system designs.

Loss of consciousness occurs because as positive 'g' forces push down on the pilot's body, the G-force overcomes the ability of the heart to pump oxygenated blood upward into the brain. Blood begins to pool in the lower extremities, while blood circulation to the head is reduced. When blood circulation to the head is sufficiently reduced, the oxygen supply to the brain is inadequate and loss-of-consciousness occurs.

Early vintage aircraft were not capable of producing very high g-forces and were limited to relatively slow onset rates through flight control systems designed to prevent the pilot from overstressing the aircraft. Aircrew found that loss-of-consciousness was preceded by a visual warning, a dimming or loss of peripheral vision referred to as 'tunnel vision' or 'grey-out.' If the pilot ignored the visual symptoms of impending 'black-out' and continued to pull high 'g', consciousness was lost. Thus, pilots learned to fly up to the point when their vision began to dim, and then unloaded the G-force on the aircraft before losing consciousness.

Today, however, aircraft can attain high g-forces at onset rates so rapid that the pilot looses consciousness without passing through the 'grey-out' phase. The supply of oxygen to the pilot's brain can be stopped so abruptly that the pilot is moved from a state of consciousness to unconsciousness without warning. Secondly, due to the increased g-onset rates, the cardiovascular system has less time to adjust to increasing g-force. Finally, current aircraft are capable of sustained high-g manoeuvres up to 9g, which can far surpass the endurance of the pilot.

As soon as the g-forces are unloaded, oxygen can once more reach the brain and consciousness returns, recovery, however, is not instantaneous. While consciousness can return within about two seconds of off-loading the g-forces, the control of body functions does not return immediately. There is a period of incapacitation during which the pilot, although conscious, is unable to take effective action. Only after this period has elapsed can the pilot begin to become situationally aware and resume control of the aircraft. Within the geometry of the low altitude and high speeds flown during display flying, there is almost no recovery time available to prevent disaster.

G-LOC has been suspected as the primary contributor to several of the airshow accidents, in particular the BAE Hawk 200 crash at Bratislava, Belgium in 1999 and also the two Northrop F-20 Tigersharks in South Korea (1984) and in Newfoundland, Canada (1985). Northrop Corp.'s F-20A Tigershark prototype fighter aircraft was flying a practice demonstration at the Goose Bay Airport, Labrador, Newfoundland on 14 May 1985, in preparation for performances at the upcoming Paris airshow. During the final aerobatic manoeuvre of the five-minute flight, the aircraft deviated from the planned profile and entered a shallow wings-level descent. The descent continued until the aircraft struck the ground, killing the pilot, David Barnes. The Canadian Aviation Safety Board determined that the Northrop pilot became incapacitated during or following the final high-g pull-up maneuver and did not recover sufficiently to prevent the aircraft from striking the ground.

In another possible G-LOC case, a media report " *Blue Angels* October '99 Crash Report" dated 11 February 2000, the Pensacola News Journal, Staff Writer Scott Schonauer wrote that additional speculation had emerged regarding the accident causal factors. "A prior rib injury may have momentarily impaired a Navy *Blue Angels* pilot and caused the crash that killed him and another pilot last October. An investigation determined three possible causes for the accident, but the rib injury is 'the most likely scenario,' the Navy's air training chief wrote in a report which found that Lt. Cmdr. Kieron O'Connor's injury might have made it difficult for him to tense his abdominal muscles to avoid blacking out during a high 'g' turn; constricting the abdominal muscles that keeps blood in the brain".

In supporting the injury theory, Read Adm. Mike Bucchi rejected the conclusion of the investigating officer who wrote that a bird strike or close pass likely distracted O'Connor as he made a left hand turn. Bucchi also disagreed with a third scenario, in which O'Connor may have been briefly distracted and inadvertently allowed the aircraft to lose altitude. There was no evidence of a mechanical problem.

The report said O'Connor hurt his ribs six days before the accident during a squadron game in which everyone drops to the ground from their chairs. He accidentally landed on his side against Colling's knee. The Navy refused to explain why the pilots were playing the game and the report gave few details about it. Cmdr. John Ottery, *Blue Angels* public affairs officer said: "the report speaks for itself" and referred all questions to the chief of Naval Air Training. No administrative or punitive action would be taken against anyone because of the accident.

Shortly after injuring himself, O'Connor notified the flight surgeon about pain. Although X-rays found no broken ribs, O'Connor winced when pressure was applied to the injured area. Several airshow pilots did not concur with the findings in the report. It is difficult to accept that a pilot of O'Connor's capabilities would pull himself into a sleep without unloading the aircraft, hook or no hook. He knew how he felt and he knew what happens at high radial 'g'. It would have been completely out of character for him to simply pitch the aircraft into a highly loaded turn, knowing full well what the consequences could be.

Because O'Connor was flying as low as 400 feet above ground level, losing his bearings for even a few seconds could lead to a crash, the report indicated. Before flying, O'Connor told his commanders and colleagues that he had fully recovered from the rib injury receive a week earlier. On the day of the crash, O'Connor apparently violated Navy regulations by taking the over-the-counter painkiller Ibuprofen, found in Advil and Motrin, without consulting the squadron's medical officer. "There are a great number of medications that are thought to be harmless, and I would put aspirin and Motrin in that category," said Capt. Fanancy Anzalone, director of academics at the Naval Operational Medical Institute in Pensacola. "What I would be concerned with is the reason they're taking the medication. The rule against self-medication is occasionally broken by pilots to treat headaches or minor muscle pain with Ibuprofen", Anzalone said, "but only if they are certain that the injury will not affect performance".

"The bigger issue is that if he had a problem in that area, he should have stepped up to the plate and said, 'I shouldn't be doing this,'" said Lonny McClung, a retired Navy captain and president of the Tailhook Association, a military-affiliated group of Navy pilots. The ill-fated flight was O'Connor's second that day in preparation for an airshow at Moody Air Force Base near Valdosta, and he had shown no problems with high-g aerobatics in the first flight. But if the painkiller began to wear off during the second flight, it could have made the hook manoeuvre painful and difficult to maintain. The technique requires taking a very deep breath, and tightening all the muscles of the lower body. "You bear down like you're trying to have a real hard bowel movement," Anzalone said. "Pilots learn how to control the hook very well."

Colleagues told investigators that O'Connor was a conservative pilot, and said the risk associated with flying while injured would be out of character for the 35-year-old. "O'Connor would not be the type to go flying if he was not well enough," testified Cmdr. Patrick Driscoll, commander of the Pensacola-based *Blue Angels*. "We don't want to put other pilots at risk by pushing the limits," he said.

The original report, written by Cmdr. Brian Toon, presented the blackout theory, but suggested that O'Connor was more likely trying to avoid hitting a bird. "While there is no evidence of a bird impact through the canopy, a close pass with a large bird is likely," Toon wrote. "This is the most likely scenario." Most of the eyewitnesses, including other pilots and ground crew, reported seeing large birds in the area, but none saw one hit O'Connor's Hornet. In a letter attached to the final report, the admiral in charge of naval air training said the bird theory was "not sufficiently substantiated by the findings of facts. While the available information does not conclusively point to a single cause for the mishap, the blackout theory is the most likely scenario," wrote Rear Adm. Toney Bucchi.

Squadron members disagreed in their testimony, evidenced by Lt. Cmdr. David Silkey, a fellow *Blue Angels* pilot and O'Connor's closest friend on the team. "I know in my heart that mishap wasn't caused by the 'g's," Silkey said. O'Connor's father said the conclusions of the report were not important to the family. "Nothing that's in that report makes a bit of difference because it's not going to bring him back," David O'Connor said. "I don't think things will ever get back to normal for this family." (Matthew I. Pinzur, Morris News Service)

Military experience has concluded that an anti-G suit can provide about 1 g additional protection and a properly performed straining manoeuvre can provide about 2 g of protection. In combination, and without any further tolerance enhancement, an experienced pilot could tolerate about 7.5g before beginning to loose visual acuity. The factors that may affect the pilot's ability to tolerate high g are individual differences in physiological responses, physical fitness, dehydration (lowers g tolerance), nutrition (missing meals reduces g tolerance), recency of g exposure (tolerance declines rapidly if exposure to g is infrequent) and most illnesses reduce g tolerance.

So, as the physical demands on the display pilot have increased enormously, the increased performance and aircraft agility have induced a requirement from the pilot for physical endurance to handle high g-loads, high g-onset rates, very disorientating roll rates and high acceleration rates about all three axes. The criticality of pilot anticipation, reaction and response times in the face of such high performance, has added to the hazards facing the display pilot.

DISPLAY PILOT TYPE EXPERIENCE AND CONTINUATION TRAINING

Besides the hazards posed by the close proximity of the ground that display pilots must be aware of, there is the question of the pilot's skills level, experience and continuation training. Analysis of airshow accident reports indicates that the major percentage of airshow accidents involve high time pilots, certainly in terms of total flying hours and years in the cockpit, but not necessarily on type. Sadly, in many cases, they are veterans of the airshow world having spent years practicing and displaying aircraft. Airshow pilot Carey Moore was killed in the Hawker Sea Fury crash while performing at the Sarnia International Airshow in Sarnia, Canada in July 2001; he reportedly entered an incipient spin after doing a climbing turn from a slow, low-level pass. The aircraft dived from a low height of approximately 500 feet above ground level, impacting at such a steep angle that the aircraft was nearly vertical, according to the Transportation Safety Board. Moore's aircraft had performed had performed impressively during the previous month at the Hamilton airshow, said veteran pilot Bill Randall.

Creating a crater more than a metre deep and two metres wide, investigators concluded that the aircraft's airspeed was at least 240 km/h at impact. Witnesses said the aircraft banked over the farm, dropped and landed like a folded accordion on the ground. Lloyd Blondin of Sarnia said the left wing on the aircraft was high as it turned. "It just looked like it rolled over," he said. "The last thing I saw was the blue belly of the aircraft before it went down into the trees." The only other evidence of the crash beyond the wreckage, was a snapped hydro-line leading to the farmhouse. The force of the impact was clear from the damage, most of the aircraft was unrecognisable, however, the tail's rudder was still intact, as was one of the five propeller blades that stuck out of the ground. (Free Press Reporter & Special to The Free Press Sarnia)

The pilot had a lot of time on T-28's and similar category aircraft but reportedly only had about 20 hours on the Sea Fury. The question that begged asking was: "is 20 hours on type sufficient to be putting on a public display at low-level?" The pilot of the Kingcobra crash at Biggin Hill in 2001, according to the AAIB accident investigation report, had flown it in displays on at least ten occasions since 1998 and was known to have enjoyed flying the aircraft. As a holder of an Airline Transport Pilot's Licence, the 43-year old pilot had a total of 7,730 flying hours of which only 13 were on type. He had flown 143 hours during the last 90 days and 56 hours during the last 28 days and held a current Display Authorisation (DA) for a Category C aircraft. The pilot of the F-86 Sabre that crashed at El Toro MCAS in May 1993 pulling out of a loop reportedly had 47 hours on type; unfortunately the percentage of the 47 hours actually flying low-level aerobatics was unknown.

The 69-year-old pilot of the De Havilland Venom that did an inadvertent wheels-up at the Biggin Hill Airfair 2001, was highly experienced with a total of 5,574 hours of which 242 were on type but he had only flown 10 hours in the last 90 days and 6 hours in the last 28-day period. Although the pilot had over 200 hours flying experience on type, this was only his second flight on type in eight years and only his second flight in this specific aircraft, G-GONE. Even the most experienced pilot in the world is fully capable of doing an inadvertent wheels up, but using a pilot that has flown only two flights on type in the last eight years at an airshow, even if it is only for flypasts, raises several questions regarding display flying qualifications and supervision.

The official US Navy report on the QF-4S accident at the Pt Mugu airshow in 2002, assigned 'Pilot Error' as the primary cause and ruled out mechanical failure, birdstrikes or faulty maintenance as causes of the crash. The report blamed the pilot's handling of the jet of the run-in break manoeuvre and the veteran pilot's relative inexperience with F-4 aircraft. Although the pilot, Cmdr Norman, had racked up more than 3,300 hours of flying time in military jets during his sixteen-year career, he had logged just seventy-nine hours flying the QF-4S, an experience level that was considered "below average," by the Board.

Investigators concluded that besides aggressive handling, the pilot did not account for the increased weight of the aircraft, which was about 4,000 pounds more than the aircraft was carrying during a practice run three days earlier. Although an experienced aviator would normally allow for the different fuel condition and adjust as needed to fly the aircraft, more awareness about the inexperience of the pilot with regard to the heavy landing condition should have resulted in calls before the break such as, “QF-4s, we’re heavy, watch the pull,” the report stated.

The investigation’s findings prompted Navy officials to increase minimum experience criteria for pilots in Point Mugu’s QF-4 programme. Only pilots with a minimum of 200 flight hours on F-4s of all types and 600 to 800 hours of tactical jet experience such as flying in formation would in future be assigned to fly the QF-4S. Under the new standards, Norman would not have been allowed to fly in the airshow.

To answer the earlier question therefore, there are definitely two distinct groups of differing opinion offered, the one a 'qualified yes', the other, a definitive, 'no'! The real answer is, however, more complex. If the pilot was in the air force flying a particular aircraft type, the military authorities would certainly not permit the pilot to publicly display the aircraft with only twenty hours on type. Regulations exist within the military that specifies the minimum requirements before a pilot may be allowed to demonstrate the aircraft publicly at low-level. The regulatory control of air force aircraft is definitely more rigidly enforced whereas private owners of aircraft and non-legislative airshow bodies serve in a guidance capacity only, leaving the owners, without the oversight of a ‘guardian angel’.

It is normal practice for a military pilot to first successfully complete a type conversion then an operational conversion as an absolute minimum before being considered for low-level aerobatic display flying. Thereafter it is the prerogative of the Squadron commander to nominate a suitably experienced candidate for consideration; this could imply that the candidate would have at least approximately 100 hours on type, be flying current on type and in low-level aerobatic displays. In reality, the pilot would have had to work his way up through the hierarchy within the squadron and would inevitably be a fairly senior member and probably with a few hundred hours on type.

In theory, however, a highly experienced display pilot with similar type airshow experience could display the aircraft in public at low-level. The secret here however, is to understand the shortcomings in the particular pilot’s experience on type and to design an airshow sequence that would display the aircraft to the public without endangering the pilot or the spectators. More particularly, the sequence would be designed to match the pilot’s experience. It would certainly not be ‘edge of the envelope stuff’ but would provide the spectators with the opportunity to get a ‘taste of nostalgia’ or of whatever performance the aircraft was potentially capable of demonstrating.

What is evident is that departure type accidents of vintage warbirds have certainly taken their toll. Some vintage high performance aircraft were, and are still, the most ‘powerful propeller driven beasts’ yet designed, their engine output exceeding 2,000 hp in many cases. Such aircraft are capable of generating immense torque (power) values which when coupled with the marginal static stability characteristics of some vintage designs, high wing loading and early generation aerodynamics, produces an aircraft susceptible to departure with deceptive spin characteristics. The bottom line is that even the most experienced pilots can get into trouble with the aerodynamics and performance of the earlier vintage aircraft that they entrust their lives with, especially if they have insufficient experience on type.

It is a fact that the aircraft of that era were not as forgiving as the more modern designs, stall and departure warning characteristics were deceptive and not easily distinguishable. Departure recognition was one of the most important survival tools of that vintage of pilots. Although low-level display flying is a “seat of the pants” type flying, the “energy gates” must still be passed through safely with the aircraft fully under control. Pilots with experience gained in operating the aircraft to its limits in combat, would have learnt to ‘feel’ the aircraft.

Within the analysis of 118 accidents covered in Chapter 3, a total of 24 Loss-of-Control accidents contributed to approximately 20% of the airshow accidents. The relatively high percentage of accidents of this type also highlights the requirement for above average handling and flying capabilities by the display pilot, especially critical in the realm of demonstration flying. Loss of control accidents included the Russian Tu-144 steep pitch-up which consequently led to loss of control and catastrophic structural failure at the 1973 Paris Airshow, the entry into a spin from a wingover by the De Havilland Mosquito at an airshow at Barton, UK in 1996 and the departure and spin of the P-63 Kingcobra at Biggin Hill Air Fair in 2001. Also included under loss of control are the two Hawker Sea-Fury accidents, the first on the ground during the landing roll-out where the pilot was killed when the aircraft flipped onto its back at the EAA Sun ‘n Fun 1996 and the second, Casey Moore’s loss of control from a climbing turn at Sarnia, Canada in 2001.

Casey Moore had relatively very little experience flying single-engine fighters when he bought the Hawker Sea Fury that January. It was a gorgeous beast that he put together, an aircraft that travelled faster than any other single engine fighter in history. Moore had flown lighter trainer aircraft that are easier to manoeuvre and as of the previous month, had flown the Sea Fury fifteen times. “It’s not an easy aircraft to fly,” said Jim Harris of the Transportation Safety Board, which investigated the crash.

Those who have flown similar fighters say the description of the Sarnia crash by eyewitnesses left one likely conclusion, Moore made a mistake and stalled the aircraft. In a light trainer aircraft, such mistakes can be corrected, but in a heavy fighter, such an error, at low altitudes, is usually fatal. Pilots call it the manhole cover syndrome - it’s so big and heavy, it falls like a manhole cover - stall below 3,000 feet and you’re in a world of hurt.

The Washington Museum was able to buy the aircraft in 1998 after its owner, Jack Rogers of Illinois, was killed as he piloted another fighter, Reynolds said. The museum, faced with budget constraints, sold the Hawker Sea Fury since it was its only fighter that was not American and it drew less interest from museum patrons. The selling price was about $300,000, less than the typical cost of a Sea Fury because it had an original engine for which it was difficult to find spare parts. The death in a Hawker Sea Fury was the second in a two-month period. On 12 May 2001, a pilot was killed in the UK when his Sea Fury flipped while landing at an airport north of London. (Jonathan Sher, and Allan Woods, Free Press Reporters)

Returning to the original argument, regarding display pilot experience and continuation training, unfortunately vintage warbirds are not readily available for modern day pilots to really get to know the aircraft as well as the actual wartime pilots, yet feel obliged to operate the aircraft on the edge of the envelope and this is possibly where the problem lies with not only flying vintage warbirds, but displaying them in an aerobatic sequence without the pilot having the necessary experience.

In a discussion with an Inspector of Air Accidents with the AAIB in the UK during 2002, he admitted that he had some fairly strong views on the way that display flying had been regulated in the UK in recent years, although they were clearly not those of the AAIB. “It seems to me we have forgotten some of the real basics with regard to aviation in an area where the margins for error are necessarily reduced. Currency is a major issue but we see individuals with precious few hours on type or on solo display being given clearances to display down to, or even below, heights that we see the professional teams”.

“Of course as soon as vintage types enter into the equation, there are immediate difficulties balancing the preservation of fatigue life with pilots retaining display currency. I also believe that there is an element of improvisation in some display routines that I know in the past has led to difficulties. I think that any display work-up should be a controlled graduated work up with carefully defined currency requirements. I suspect that the CAA regulators would claim that their current system does just that, but I have my doubts. Enough of these rantings!"

But there is more to pilot vulnerability than meets the eye and to this end it is necessary to consider the philosophy of display flying training and try to correlate this with display pilot decision-making. Highly experienced Boeing McDonnell Douglas F-18 demonstration pilot, Ricardo Traven, has some profound and possibly controversial views on display flying training. "It is my very strong impression that a pilot's critical thinking paths that have been programmed over a career of safe and professional flight conduct, are altered by the manner in which pilot's train for an airshow. For example, throughout my career as a fighter pilot and test pilot, I have needed to learn new manoeuvres and then demonstrate my ability to perform them before moving on to the next level of learning. Airshow flying is very different in that pilots practice a routine at a safe altitude then continue to fly the exact same routine over and over again at lower altitudes until the final show altitude is reached. However, even after the final altitude is reached, the same routine is practiced over and over again in an attempt to achieve perfection. This constant practice and flying the same routine results in a change in the way critical thinking occurs".

"Allow me to explain. In the same way that a dog is trained to sit or to retrieve an object, the training of a pet does not conclude on the first time that the desired response is achieved, but continues over and over again until it becomes second nature, the result of repetition. Consequently, the training for an airshow has, in my opinion, many similarities with how one trains an animal. This raises a very interesting concept regarding judgement that I wish to use an analogy. The family pet will not normally run across a busy intersection, however, if a ball is thrown across that same street and the dog is told to 'fetch', it would be expected that the dog would run across the street with no regard for personal safety or truly understanding the danger in the situation. I contend that a pilot's 'airshow judgement' can become distorted in the same way by the training. After training for a specific task for weeks and months the expectation to perform on airshow-day is similar to tossing the ball across a busy street. The desire by the airshow pilot to perform, like the dog, is based on an eagerness to please. As a result, the same pilot does not inherently view the situation with the same criticality as he or she would when flying elsewhere or doing a different task not practiced 'ad infinitum'. It has been said of display pilots killed at airshows that they were so professional and so mature that it seems impossible to think that they would have made such silly errors in judgement on airshow-day".

"Based on my own experience, I have tried to understand why a show pilot will do something the same pilot would not do under different circumstances. I flew an airshow in weather that I knew was below limits before take-off. After that event, I concluded that I did not fly the show as a result of over-confidence or cockiness, something I would readily admit to now. On the contrary, the motivation to fly was based on a very strong desire to please - when the control tower said: "cleared take-off" on that day, they might as well have said, "go-fetch". My own judgement had been compromised. Looking back I have become acutely aware that my motivation to fly and my desire to please, that run very strong when preparing for an airshow, directly conflict with my judgement to stop or discontinue a programme under adverse conditions. Train like a dog and you will soon think like one!"

Traven's theory certainly seems to hold good in several accidents in which the display pilot's behaviour was irrational, could not be adequately explained. All these accidents in which the accident investigators cannot find a rational explanation for the pilot's decision – well, the 'go-fetch' syndrome could be applicable. Finally, the actual flying of any aircraft is generally not that difficult, but the skills required to demonstrate an aircraft optimally, is a special skill that not only requires experience, but intensive training on the specific type and intensive training on the specific routine, failure to recognise this fact will continue to result in many more accidents worldwide.

THE PHILOSOPHY FOR SPIN TRAINING?

Bearing in mind the very low probability of surviving a low altitude spin, the question of spin training remains moot. For spin training to be effective, however, realism is essential and it has to go far beyond a simple one-turn spin, it has to look at the permutations of manoeuvres and handling scenarios that can lead up to the spin and give pilots the confidence and skills to fly properly in those regimes. Is spin training a waste of time? In the final analysis, no, not if it's done correctly - but even then, it still won't protect a display pilot from extreme lapses of judgement. Once again it is pilot judgement rather than stick and rudder skills that appears to be a primary factor in the error chain.

The bottom line is that avoiding high angles of attack in manoeuvres close to the ground is vitally important. Since 90% of spin accidents are caused by a departure that occurs at too low an altitude for a safe spin recovery, it really becomes a debatable point whether knowing how to perform a spin recovery, would make much difference. Preventing the stall is therefore far more important in the typical spin accident error chain. For aspirant display pilots, the question of spinning is often approached with trepidation and the common question is: "What is the value and the advantages of spin training for display pilots?" Well, the first bit of advice is understanding that spin recovery is not some 'black art'; it is not some mysterious tryst that should be regarded with trepidation. Provided of course that a thorough understanding of the theory exists and adequate practice is flown, the risks are manageable. After all has been written to this point, it is logical that the aspirant aerobatic display pilot must fly a thorough spin and stall programme BEFORE commencing with aerobatics. But why?

An aerobatic pilot can certainly end up in a spin from just about any aerobatic manoeuvre if it is 'screwed-up' badly enough and many novices are unsure about the departure possibilities in an 'overcooked' manoeuvre. As an example, a common concern is entering a spin, either erect or inverted, from a mishandled manoeuvre such as a loop. However, if the pilot is flying coordinated at the top of a loop and the aircraft stalls, well, just reducing the angle of attack by a slight reduction in elevator pull force will prevent the aircraft from penetrating the lift boundary. Continuing to let the aircraft fall-through without adverse yaw inputs from the rudder, aileron, engine torque or any other form of sideslip, the aircraft should fall through under the effect of gravity and accelerate out of the stall – the amount of height required for this type of recovery pull out, would of course, be significant.

So, how susceptible is an aircraft to departure and spin? Disregarding engine torque, for an aircraft to enter a spin, either erect or inverted, the aircraft must first pass through the stall regime, depart and then enter the spin. The critical path for successful spin recovery is the pilot's early recognition of the characteristics but this could be complicated by the inconsistency or lack of adequate warning of departure in some aircraft. To enter a spin usually requires some form of aggressive input, either through mishandling by the pilot or through engine torque.

In the worst-case scenario of a spin, the aircraft could even crossover from upright to an inverted spin or if aileron and power are added during the spin, the aircraft could even enter a flat spin. Departure and spin are, therefore, typically things that could happen if the aircraft is 'poked in the ear' or grossly mishandled by the pilot. The exact contribution of engine torque is an unknown variable, however, what is certain is that the higher the engine torque, the higher the destabilizing pro-spin yawing moments and slipstream effects.

While the display pilot might inadvertently stall or even spin if the vertical is really manhandled by pulling way too hard on the backside of the loop, the stall and the subsequent spin, will all likelihood be an erect spin. The only way to get into an inverted spin would be to stall and depart from a negative angle of attack by pushing forward on the stick or using engine torque or adverse aileron yaw to generate the negative angles of attack through gyroscopic precession. There can be no inverted spin without the aircraft first passing through an inverted stall and for that, a negative angle of attack must be generated.

In Duane Cole's books "Roll Around a Point" and "Conquest of Lines and Symmetry", he expressed the opinion that pilots rarely get into inverted spins, although they think they did. An inverted spin implies a stall on the underside of the wing, an 'inverted stall', not just an inverted attitude. (ie 'inverted' implying negative G, not an inverted attitude) To prove this point, even if a snap roll is 'bungled' while inverted at the top of a loop and the aircraft departs, it will still converge into an erect spin, not an inverted one, as long as no forward stick pressure is applied to induce a negative angle of attack. Some aircraft used for 'soft' aerobatics such as the Cessna 152 Aerobat, simply will not easily enter an inverted spin, the aircraft is too 'nose-heavy' (insufficient pitch authority to drive the angle of attack negative) and just doesn't have enough rudder authority (insufficient rudder power to generate the required pro-spin yawing moment). With the right combination of engine torque, however, it is feasible to find the right combination of torque, rudder and aileron input to produce an inverted spin, but not without good piloting skills.

Taking this principle one step further, and by way of example, consider the 'avalanche' - stall the aircraft by pulling hard while the aircraft is in an inverted attitude and then enter a spin by giving full rudder. The aircraft will tumble a bit but the aircraft will end up in an erect spin and recover in the usual way, even though the aircraft entered the spin from an inverted attitude. Basically, in terms of spinning options, the aircraft can enter a normal upright spin from an inverted attitude by pulling back or conversely, enter an inverted spin from upright by pushing forward.

Although concern for the inverted spin is quite well founded amongst novices, the real threats of entering an inverted spin from aerobatics will more than likely originate from a poorly performed hammerhead (stall-turn), 'tailslide' or Immelman (roll off the top), rather than the loop. These are possibly greater hazards to the novice display pilot as they're likely to underestimate the spin potential which is why it is not a good idea to do any of these manoeuvres without some form of training in erect and inverted spin recovery.

Not that an inverted spin is difficult to recover from, but even experienced pilots have great difficulty in determining the inverted spin direction, especially on entering an inadvertent inverted spin. In an erect spin, the roll and yaw are in the same direction but in an inverted spin, the roll and yaw are in opposite directions and to the pilot suddenly caught unawares by an inadvertent inverted spin, it is possible for the inexperienced pilot to misinterpret the direction of the spin. If the pilot does not know the direction of spin, kicking the correct anti-spin rudder is not possible – it's as simple as that.

Besides the physiological aspects of hanging from the seat straps, feet flailing off the rudders from the negative 'g' or the pilot's perception of the horizon, it is this disorientation of spin direction that is the main challenge to the pilot. In an erect spin, the aircraft is usually pitched nose-down at approximately 45º but in an inverted spin, the nose is just below the horizon and the earth appears above the pilot and the sky beneath – so the display pilot must understand the problem of spatial orientation.

By way of an example, consider the UK Air Accident Investigation Board (AAIB) report of a spin accident in a Pitts S-1C during 1997 (AAIB Bulletin No: 8/97 Ref: EW/G97/04/03) which provides a real world example of the hazards. The highly experienced (10,036 flying hours) competition pilot had completed two aerobatics sequences in preparation for a forthcoming competition. The weather was excellent at the pilot's operating height between 2,500 feet to 4,000 feet above mean sea-level (amsl).

The aerobatics sequence went as planned until the top of a stall turn. The airspeed was slightly low as the pilot applied full left rudder in attempting to complete the manoeuvre on a specific heading and he could remember advancing the throttle slightly and applying full forward control column. Almost immediately, the aircraft flicked into an inverted spin. The pilot was so surprised at the high rate of descent that he could not recall his precise recovery actions. He could however, remember that the throttle was fully retarded and that he brought the control column fully back with the ailerons central.

With full left rudder still applied, the aircraft was not recovering and the pilot thought that he may then have relaxed the rudder application or even applied some right rudder; he did not check the turn direction from the 'Turn and Slip' indicator. However, he noted the altimeter indicating 2,000 feet amsl and as this was his self-briefed abandonment height, he immediately went for his harness release and bailed out of the aircraft. He was aware of being thrown forcibly out of the cockpit as he released his harness and the parachute descent was uneventful, the pilot landed a few hundred yards from where the Pitts had crashed.

The pilot had made weight and balance calculations prior to flight and subsequent to the accident, he rechecked the figures and confirmed that the weight and centre of gravity of the aircraft were within the correct limits. He also stated that the aircraft had been fully serviceable during the flight and acknowledged that it was a mishandled stall turn that caused the loss of control. With the short time between this loss of control and his decision to bail-out, the pilot was not certain of his recovery actions; he considered that he may have used some incorrect actions. He had reasonable experience in aerobatics and had completed training in both upright and inverted spinning but was surprised at just how quickly the aircraft entered the spin and the extent of his disorientation. He did however acknowledge the value of his habit of wearing a parachute during aerobatics flights and of his pre-planned abandonment height.

So what is it that makes the vertical manoeuvres susceptible to inverted spins? It is necessary to consider the dynamics remembering that for an inverted spin to occur, the aircraft must first reach the negative stalling angle of attack before it can enter the inverted spin and then of course, as in the erect spin case, pro-spin sideslip must be generated. Pulling up into the vertical for the hammerhead stall, the attitude is very near to the vertical as it is required to be for the stall turn and the pilot is required to keep the forward stick pressure to prevent the aircraft from coming over on its back – if the push force is excessive, negative angles of attack can easily be induced.

The application of full rudder to get the nose to yaw in the direction of the stall-turn also causes the 'outer wing to lift' which in turn requires the pilot to hold off the outside wing with aileron or else the aircraft does not pivot about the normal axis at its apex as it should in the stall turn. Instead, it falls over onto its back – not a pretty sight for the connoisseur, flying, or watching. The control dynamics in this posture are therefore, slight forward stick introducing a negative angle of attack, rudder yawing the aircraft about an imaginary point and the opposite aileron keeping the aircraft from coming over on its back. These control positions can provide the necessary aerodynamic moments to generate the negative angle of attack and sideslip to drive the motion to departure and consequent inverted spin.

The 'tailslide' in particular, by its very nature and definition in which 'the aircraft stalls going straight up and the falls straight back flipping top side down to a vertical down line, is another manoeuvre increasing the susceptibility to inverted spins. When not performed correctly, this trajectory can generate high values of negative angle of attack as the aircraft whips downwards through the bottom of the hammerhead. It is during the 'flip-over' itself, when the nose whips through, that large values of negative angle of attack can be generated. The application of any rudder, aileron or engine torque can provide the necessary pro-spin yawing moments required to drive the inverted spin.

Similar control position dynamics exist for the Immelman. Coming up over the top of the half-loop, the pilot is required to apply forward stick to check the nose on the horizon before doing the aileron half-roll to erect. Because of the relatively low aerodynamic power of the rudder and aileron usually existing at the low speed on top of the loop, co-ordinated, relatively large applications of rudder and aileron are required in the direction of the roll. Now, in this particular manoeuvre, contrary to the hammerhead stall and the tailslide, the engine will not be throttled back and can be generating high torque values, so the destabilising torque and also the slipstream contribution will be high and mishandled or uncoordinated control response, could lead to an inverted spin.

Considering the foregoing discussion, one really important point though, occasionally pilots intentionally spin non-spin approved aircraft and because they're able to recover, they conclude that the aircraft is really safe to spin after all. Some pilots incorrectly suggest that spin restrictions are based only on liability issues and come from the manufacturer's lawyers! NEVER spin an aircraft not approved for spinning!

The fact that it can be done and the 'spin' recovered from, is a trap. That one turn 'spin' is really not a spin at all, but only an incipient spin, which is really only an aggravated stall. The real spin develops as a progression of the incipient phase, the dynamics of which are very different from the incipient spin. Many non-approved aircraft can quickly enter a flat spin mode after the first or second turn and that spin could be non-recoverable!

Spins involve an aerodynamic region that features angles of attack occasionally exceeding 45º and even the best computational fluid dynamic analyses have a hard time accurately modelling such extraordinary angles of attack. In the case of an experimental aircraft, there is no assurance that a homebuilt can recover from an incipient spin. The variables involved in spin recovery are complex, including tail size, blanking of the empennage surfaces at high angles of attack, propeller slipstream effects and aircraft weight distribution. There is no assurance that the so-called standard spin recovery technique will work on any given experimental. Older generation tail-draggers like the J-3 Cub, Taylorcraft, PA-18's, etc readily spin, and most do not have stall-warning devices.

Normal Category single-engine aircraft and Utility Category aircraft that are placarded against intentional spins have usually only demonstrated recovery from a one turn incipient, and that test is done only to check the aircraft's controllability during aggravated stalls, nothing more. Beyond that, all bets are off since there are no guarantees on what the aircraft will do in that regime. The placarding in some instances is there to indicate that the aircraft will not spontaneously recover from a spin, but in other aircraft, it may indicate that a spin cannot be recovered at all, or in some cases, it is non-recoverable after a certain number of revolutions.

When an aircraft is certified as "spins prohibited" it simply means that the manufacturer did not demonstrate to the FAA or any other certification authority, the necessary items required to certify it for spins. Pilots are left to their own in trying to guess why the manufacturer did not seek spin approval. Many times it may be because its too hazardous, other times it may be the complexity of the approval process, other times it may be a liability issue and other times the costs of the test programme, especially on the smaller general aviation types. If an aircraft is "not approved for spinning", then it goes without saying that aerobatics should not be performed in that aircraft. The bottom line is that if any aspirant display pilot is going to enter an aerobatics training regimen, a stall and erect spin programme is essential while an inverted spin programme is considered highly desirable, if not in practice, than at least in the theory.

So, what does an aspirant display pilot need in terms of a spin training programme? Well, to start with, preferably a spin endorsement prior to performing solo spinning or aerobatics while inverted spinning is the subject of a separate endorsement. The ground school should cover the basic theory of spinning, instrument indications, aircraft limitations and specific spin characteristics of the aircraft type used for training. This ground school syllabus should include the effect of loading and control actions, explanations of different spin and recovery characteristics for different types of spins and competition spins.

The basic spin flight course should include a revision of stalls and incipient spins, spiral dive recovery, spinning with recovery technique per Flight Manual of the aircraft used in training and recoveries from unintentional spins. Of course, there is more to spinning than a basic course – each pilot's own training programme will depend on the specific individual's objectives and the type of aircraft. FAA Advisory Circular AC No: 61-67B explains the stall and spin awareness training required under Part 61 of the Federal Aviation Regulations (FAR) and offers guidance to flight instructors who provide that training.

Since the early days of flying, both stalling and spinning have been significant causes of display accidents and an economic design solution to the problem of spinning has not yet been found. There's always been a lot of hype about spin training but it's difficult to get too enthusiastic for spin training reading the accident narratives involving accomplished aerobatic pilots who fell into the spin trap. There are, however, many proactive decisions that display pilots can make that will substantially lower their chances of a spin accident - an intimate knowledge of the specific aircraft's departure characteristics, good judgement, common sense and discipline - something a pilot cannot buy or be taught. Improving pilot judgement and basic airmanship would go a long way in complementing spin training programmes thereby making inadvertent spin accidents far fewer.

THE VULNERABLE DISPLAY PILOT

The three pillars of the display pilot's survival structure are skill, judgement and decision-making. For the unsuspecting display pilot in the hostile environment of the display arena, there are many threats lurking; mostly well disguised; it takes a well-disciplined display pilot to recognise and then to counter such threats. Typical examples are distraction, whether it be in the form of cockpit workload or ergonomics, administrative overload caused by having 'too many fingers in the show organisation pie' or even ejection decision making, the threats are ever present in their various disguises. The display pilot must know that they exist and be able to recognise them.

Particularly important is for the display pilot to be aware of personal shortcomings and that no matter how good a pilot is or how much practice has taken place, the pilot is only human and human error is the highest risk factor in general aviation but specifically display flying. And then there is Man's dubious ability to make decisions under life-threatening conditions which can best be typified by considering the ejection decision. But what about Man's other survival tool – judgement, our supposed judicious, rational, wise decision making capabilities? Based on an analysis of the random sample of 118 airshow accidents in Chapter 3, it is clear that Man's staggering 78% contribution to airshow accidents makes him the weakest link in the safety chain. Considering the hostile environment of the low-level display arena and the human's physiological shortcomings, not surprising. How alert is Man to the various threats to display flying survival?

Man's weaknesses are accentuated in the categories of accidents represented by the cumulative total of Flight-Into-Terrain (32%), Mid-Air Collisions (25%), Loss-of-Control (19%) and Wheels-Up-Landings (3%). It can be concluded that some of the main 'killers' of the display pilot are lack of concentration, overconfidence and lack of current practice. There are, however, several additional factors that can bring a display to a prematurely disastrous end such as distractions during the demonstration, the mental and physical fitness of the pilot, loss of spatial awareness, the use of the pressure altimeter and in the more modern aircraft, the use of the Heads-Up Display (HUD). The display pilot must be mentally and physically prepared for all manner of distractions during the display routine, especially at critical periods, be it an unexpected reduction or increase in display time or any other distraction, an insect in the cockpit, a system going off-line, an intruding aircraft in the display area or an ambiguous radio message.

One possible explanation for the display pilot's inability to make continuous rational decisions under duress, may relate to the way the human brain processes information. The right hemisphere of the brain processes logic and analytical thought, and the left, the emotions. Right hemisphere, intense concentration during a demanding routine is relatively easy for the well-practiced display pilot under calm unstressed conditions in which collected and structured thought patterns prevail. However, when emotions are aroused, judgement is clouded. Such emotional arousal typically originates from fear, panic, distraction, mechanical failure or even physical pain.

Considering the Aeroflot Tupolev TU-144 crash at the Paris Airshow in March 1973, the official cause of the accident was reportedly that after a very steep climb, the aircraft was observed to level off very abruptly and then begin a dive. It is interesting to note that conspiracy theories speculated that the pilot, possibly startled by a close encounter with a Mirage III photographing the TU-144, overreacted causing a compressor stall. The aircraft then went into a dive and broke apart after the aircraft's design load-limit was exceeded.

What it boils down to is that when the display pilot operates mainly using one hemisphere of the brain at a time, there is no problem. But, operating on both hemispheres simultaneously seems to create the neurological equivalent of a 'mag drop' and information processing is adversely affected with a resulting error in judgement. This analogy is applicable at all levels requiring high performance from the human being and is particularly evident amongst sportsmen and it is really only the world champions that are able to rise above such pressures, but even then, not always. Tiger Woods (golfer), John McEnroe (tennis) hardly ever allowed their emotions to influence their performance. A possibly contentious method to reduce airshow risk would be to limit the age group of display pilots to the lowest risk category, screening out all but the highest time pilots for whom such activities would be 'old hat'. This would however, only be feasible in an ideal world, which it is not of course – and as has been seen, experience is no guarantee of avoiding a low-level manoeuvring accident, the variables remain complex.

The arrival of the Venom at Biggin Hill Airshow required an extensive effort by the crash and rescue services to clear the active runway of the obstruction to enable to the show to continue.(AAIB)

The weekend of 1 to 4 June 2002 was a particularly 'black week' for display flying in the UK. With all the adverse publicity generated by the fatal accidents at the airshows, little media attention was paid to the third accident of the de Havilland collection on show that day, the Venom's wheels-up landing. On arrival at Biggin Hill in the early morning, the three-ship Vixen, Vampire and Venom formation on initial broke overhead the airfield to join downwind to land. The Vixen and Vampire landed without incident but the Venom did an inadvertent wheels-up landing, blocking the active runway for the next three hours as the rescue services worked to remove the obstruction from the runway.

Wheels-up landings will always remain a threat to aircraft operations and the pilot's ego, even more so for the display pilot who does the wheels-up landing in full view of the spectators. The wheels-up landing by one of the SU-27 *Russian Knights* aerobatic team in full view of thousands of spectators at SIAD 97, Bratislava in Slovakia and the SAAF C-160 Transall during a short-field landing demonstration practice at AFB Waterkloof in 1983, serve as a small reminder of the fallibility of the pilot in the safety loop.

Also at the Paris Airshow in 1981 two C-160D Transall's dropped parachutists and then carried out a two-ship display. At the end of the display, the first aircraft landed followed by the other. The latter, bearing German colours of MBB, attempted to execute a shorter landing with a tighter approach. In the rush, the landing gear was apparently lowered but not locked. The undercarriage obviously retracted on touchdown and the aircraft carried out a belly landing. The aircraft suffered only minor damage and the crew, safe and sound, continued by having an argument on the edge of the runway. The pressure on the display pilot during a demonstration flight is higher than for normal flying; the pilot cannot afford to relax concentration until, as the old hands say; "the paper work is signed off".

In most cases, landing without undercarriage should not result in fatalities, provided the aircraft patch is straight down the runway and that there is sufficient runway length available. There are however other insidious killers stalking the display pilot; traps that pilots can get suckered into by ignoring standard operating procedures and aircraft limitations imposed by the Manufacturer. Just one such case occurred on 30 May 1988 at the Coventry airport Air Pageant. The sequence flown by a vintage jet fighter, a Meteor T7, followed the normal sequence for about three minutes until a wingover to the right which was intended to bring the aircraft back along the display line with undercarriage and flaps extended. However, although the manoeuvres up to this point seemed normal, the Meteor had been flown throughout the sequence with the airbrake extended, contrary to recommended practice.

As the pilot commenced the wingover, flaps were at about a quarter and airbrakes were extended. The undercarriage appeared to lower normally as the Meteor climbed to the apex of the wingover to the right. As the aircraft began the descending turn back to the airfield, the roll rate appeared faster than on previous occasions, the bank increased to 45º and the nose dropped. The aircraft turned rapidly through 90 deg to the right and settled into a wings level 45º dive. Shortly before impact, a roll to the right developed and the aircraft continued down as is crashed into an area of open ground close to the airfield. The Meteor was not fitted with ejection seats and there was insufficient height or time for a successful abandonment. The pilot died instantaneously on impact.

Video recording and photographs of the Meteor showed that most of the display had been flown with the airbrakes extended and examination of the wreckage confirmed that the airbrakes were extended on impact. The Meteor T7 Pilot's Notes include the following caution: *"If the aircraft is yawed at an airspeed below 170 kts with the airbrakes extended, the nose may drop suddenly and the elevators become ineffective until the yaw is removed or the airbrakes retracted. The tendency is aggravated if the ventral tank is fitted. Airbrakes should not be used at airspeeds below 170 kts at circuit height and should be in before the undercarriage is lowered".*

This phenomenon, colloquially known as 'Phantom Dive' was due to the airflow disturbance at high angle of attack caused by turbulence from the airbrakes and such effects would be amplified in the presence of sideslip. Because of the increased size of the nose and canopy, the directional stability of the two seater Meteor was degraded, especially when the nosewheel was extended and a ventral tank carried. Any sideslip at conditions of marginal directional stability would increase this effect and result in loss of elevator and rudder effectiveness and a nose-down pitching moment. When the Meteor T7 began to roll right into its final dive, the aircraft was at its lowest speed in the display, probably around 150 kts and had its undercarriage down with the airbrakes extended. The investigation considered that all of the criteria required for a 'Phantom Dive' were present and that the aircraft entered an uncommanded dive due to airbrake extension at low speed. (David Oliver)

Then there are also several recorded cases in which examples of display pilot 'administration overload' was found to be a contributory cause to display accidents. In the case of the SAAF Museum's Spitfire crash at Zwartkops Air Base (South Africa) in 2000, the Officer Commanding the Museum's tasks included Airshow Director (with a brand new safety officer), display pilot and the Airshow Co-ordinator for all the aspects pertaining to the airshow; he was also the VIP host. To quote the pilot: "my mind was not where it should have been in the days leading up to the airshow. The external pressure from the funeral arrangements, sudden changes in crew allocation and the cancellation of my solo display practice put far too much unnecessary pressure on me. There were a number of key point decisions that were made by others and myself that could have prevented the accident".

In another case in New Zealand, the Air Force Court of Inquiry found that there were no technical or mechanical problems with the Skyhawk that killed Squadron Leader Murray Neilson, aged 37, Commanding Officer No 2 Squadron, RNZAF. It furthermore concluded that Squadron Leader Neilson was suffering from chronic fatigue and was distracted in flight, leading him to perform a barrel roll from too low a height. In mitigation, it also found that he was trying to do too much with too few resources at squadron level – sound familiar?

The pilot killed in the P-38 crash at the Duxford 'Flying Legends' airshow in 1996 was also the Airshow Display Co-ordinator responsible for the planning of the display items and the choreography of the show finale, which also involved leading a mass flypast of some forty historic aircraft. He gave the daily display briefing to the participating pilots and undertook some in-show re-planning on the Sunday afternoon when the planned show sequence was interrupted by the arrival of a significant display item almost an hour ahead of the planned schedule. This undoubtedly added to the pilot's workload for the afternoon. Shortly after this, the pilot participated in the show in the lead aircraft of a pair of DH89A Dragon Rapides. After landing from this, there was then some twelve minutes before he then taxied out in the P-38 for the start of that display item. When is 'administration overload' a threat to the display pilot? How does the display pilot recognise that the focus has been diverted from the display task to 'life-threatening trivia'? When does the display pilot "knock it off"? How many display pilots, recognizing the existence of 'trivia overload' even have the 'guts' to inform show organisers of the overload threat? Not many!

Further evidence of the vulnerability of the display pilot comes with the ejection decision. In truth, at such low heights above ground level, display pilots are like a loaded gun, adrenaline maintaining all senses acutely armed, knowing that at such low-level, if anything goes wrong, particularly a collision, the natural response is to eject. There is no time for considered decision making, it's a clear-cut, pre-planned, GO/NO GO decision that a pilot must make. In fact, the decision is already made before take-off since any hesitation, even the slightest few milliseconds, could mean the difference between life and death.

One of the strongest emotions in a pilot is the fear of failure, the fear of failing a 'peer review'. Peer pressure amongst pilots is certainly unique, especially considering the 'supposed' maturity of pilots – there is a continuous, subconscious comparison of performance between pilots whether it be in aerobatics, landings, or any aspect of flying; this is a reality amongst the flying fraternity. No pilot wants to fail; no pilot wants to be involved in an incident or accident in which the term 'human error' is used to apportion blame, but the pilot's ego remains a formidable threat to his own survival – it's a pilot's thing that non-pilots may not understand.

But it is also the pilot's worst enemy, pilots may associate ejection with failure and as a result, tend to 'stay too long' in impending catastrophic conditions, trying to resolve the problem they got themselves into. Besides the fear of dying, there is a strong tendency among pilots to hang onto a disastrous situation, a situation in which the aircraft is beyond recovery with the pilot holding on in the self-belief that the situation can be saved. It is one of the overriding contributory factors to pilot's avoiding or delaying the ejection decision.

Never was the understandable fickleness of the airshow spectator, in fact of most of the human race, so exposed as during the in the world's worst airshow disaster when the Ukrainian Air Force's Su-27 ploughed into the crowds along the show-line. Heading straight at the spectator enclosures, both aircrew stayed with the aircraft right up until initial impact before ejecting, both surviving with fractured vertebrae. Several commentators, angry at the carnage caused by the accident, questioned the pilot's decision to eject, implying instead that the aircrew did not deserve to get out of the aircraft alive but this crazy emotional outburst cannot be condoned since it is an extremely negative response. What point is there in adding another two fatalities to the tragedy? Unless one has personally flown display flights, one will not fully comprehend that in this case, the pilots would have been fighting to save the aircraft all the way down. However, irrespective of the events leading up to the crash, there comes a 'point of no return' and the secret to survival remains to know where that point is – get it wrong and you're dead. In most cases, the human's ability to make such decisions leaves much to be desired, hence the large percentage of pilots that have died trying to save the aircraft or supposedly trying to prevent the aircraft from crashing into built-up areas.

One of the most difficult and controversial decisions facing the pilot prior to making the ejection decision is also somewhat of an emotional dilemma. The case of the pilot delaying the ejection decision while trying to steer the aircraft away from the spectators or public property, is a double-edged sword. On the one hand, the pilot delaying the ejection decision, looses valuable milliseconds to possibly, and then only possibly, save the lives of the spectators or public property while on the other hand, the pilot puts his own life in jeopardy – a questionable decision. However, a proper understanding of the physics of momentum could lead the pilot to selecting a completely different course of action.

The split seconds fighting the aircraft to steer it away from the crowd or private property, may not even achieve the aim of steering the aircraft way from the crowd and in the process jeopardise the possibility of survival for all parties – a lose, lose situation. Despite the emotive issues, each pilot will ultimately take the decision based on the prevailing circumstances, which in most cases, will see the pilot firstly fighting for his own survival – it is just like that, that is the way the human is designed and programmed. In most cases, only once the pilot has reached a stage in which he has satisfied his own requirement for survival, will he then try to steer the aircraft into a safe area.

In a media interview, Vladimir Toponar the pilot of the Ukrainian Su-27, openly admitted that he had struggled all the way down attempting to regain control of the aircraft. If he did not have control of the aircraft, which he did not, he would not have been able to steer the aircraft away. Only once he had the aircraft under control would he have been able to shift the focus to avoiding the spectator enclosure. In this case, however, the aircraft was on the ragged edge of a high-speed stall, there was no aerodynamic potential available to overcome the aircraft's momentum and enable him to steer away from the spectators. The decision to eject was, under the conditions of impending catastrophe, the correct one.

The human's instinct for survival is a very strong emotion that controls behaviour and response, it is not something the human actually has control of, this so called 'survival instinct'. Until one has personally experienced this emotion, it is difficult to comprehend – there are many examples of airshow crashes in which the media reports stated that the pilot tried to steer the aircraft away from the crowds, but this is mere journalistic speculation in most cases.

A case in question is the MiG-29 crash at 1989 Paris Airshow when an engine failed during a very vulnerable point in the sequence. Although there was speculation afterwards that the pilot had skilfully pointed the aircraft at the 'infield' after the failure, this was questionable. The MiG-29 was performing a 'high alpha pass', a slow airspeed pass when it suffered a previously unencountered type of engine stall. At that slow speed with one afterburner lit at that altitude, the inevitable occurred, an uncontrolled yaw/roll moment caused by asymmetric thrust (rolling and yawing into the dead engine), rolled the aircraft away from the spectators.

Yeager's autobiography states unequivocally that 99.9% of the time the pilot has only one concern on his mind, and that is to save his butt. "In an emergency situation, a pilot thinks only about one thing, survival. You battle to survive right down to the ground; you think about nothing else. Your concentration is riveted on what to try next. You don't say anything on the radio, and you aren't even aware a schoolyard exists. That's exactly how it is!" ("Yeager"; 1985 Bantam Books, page 119} For the pilot flying an ejection seat equipped aircraft, the decision to eject is available and provides the pilot with an option for survival provided the decision-making capability is not jeopardised. But, in an aircraft without an ejection seat and below the minimum bailout attitude, the pilot is forced to remain with the aircraft. The amount of control and steering options available to the pilot obviously being a function of the aircraft's residual total energy level.

Quite understandably, there is also a difference between ejection survival rates in operational service and those of airshows. The airshow arena, believe it or not, is in most cases, more critical than the operational arena in terms of ejection seat envelope limitations. This is borne out by the worldwide average of 82% successful ejections in military in-Service flying versus the sample analysis of 69%. The question that arises is: "Why is the ejection rate at airshows lower than under operational conditions". Since no official statistical analysis exists for airshow accident ejections, it is intuitive to consider operational air forces statistics for comparative purposes, which also reveal that one in five ejections (20%) is a delayed ejection.

Accident analyses have concluded that the majority of the ejection fatalities were not due to mechanical malfunctions of the seat, but rather to delayed ejection decisions. If the assumption is made that every aircrew member who decided to eject was trying to save his or her life, another question arises: Why did one out of every five crewmembers wait too long? Since out of envelope ejections usually result in fatalities, accident investigation boards can only speculate as to what the deceased pilots perceived during the last few seconds of their lives.

Further consideration of the question in Chapter 3 as to why only 36% of the display aircrew who had the opportunity to eject, did, and why the remaining 64%, did not, is necessary. Why the significantly large disparity of 36:64 between ejecting and not ejecting? As noted earlier, the answer most certainly lies in the dynamics of high closure rates versus the human's questionable decision-making and relatively slow reaction times which contribute strongly to this phenomenon, but is there more?

The single major explanation that has emerged is attributable to 'loss of situational awareness', a general term that can partially explain what happened, but not why. So, why do so many professionally trained pilots lose situational awareness in critical emergencies? To understand at least part of the pilot's behaviour, it is necessary to understand the display pilot's response under high stress, particularly stress brought on by impending catastrophe or death. This should not be confused with the long term work or domestic related stress that is usually associated with high blood pressure, ulcers, and heart-attacks, but rather the involuntary alarm or panic reaction to conditions of immediate acute stress. Stress typically associated with the realisation that the aircraft is out of control and that there is insufficient height to achieve a recovery pull-out or control the excessive nose-drop during a low-level aileron roll.

When the brain perceives the threat, it reacts by exciting the hypothalamus, which in turn, stimulates the pituitary glands to inject Adrenocortiotrophic Hormone (ACTH) into the blood. ACTH immediately signals adrenaline to secrete two substances, cortisone and adrenalin. Cortisone's effects are generally of a long-term nature while adrenalin has immediate effects. The emergency discharge of the stimulant adrenalin increases the pulse rate, the blood pressure and perspiration, while the sugar levels of the blood are raised to provide additional energy. A tiny muscle in the ear, the tympanic tensor, tightens the eardrum to increase the ability to hear, muscles tighten in preparation for immediate use, physical strength is increased, and the threshold of pain is raised. The body is now prepared to fight for survival.

The discharge of hormones also triggers the entire nervous system which becomes alarmed in preparation for survival. One interesting effect of this remarkable defence mechanism is the little discussed phenomenon of *temporal distortion*, a temporary false perception that changes the apparent passage of time. In other words, *temporal distortion* is the apparent slowing down of the rate of the passage of time and occurs under conditions of acute stress. When a pilot experiences a temporal distortion, time sometimes seems to expand and events appear to happen in slow motion. It seems that the brain instantly becomes intensely alert, increases its efficiency and begins to process information at an accelerated rate and, to the pilot, time effectively appears to slow down.

According to physiologists, the increase and sudden burst of adrenaline, blood sugar, cholesterol and cortisone into the blood allows the brain to operate at a rate of 14 to17 bits of information per second, while normal 'thinking ' is carried out at only 7 to 9 bits per second. Because of the heightened awareness, the brain already operates at a faster rate. The display pilot may not be aware of this at the time, but during the recall of the event, he/she states that things slowed down. In essence, this is the same process used in making a slow motion scene in a movie. The actual event is filmed at a higher rate of frames per second and then shown at the normal rate. The effect is a slow motion scene.

During a traumatic event where the body prepares itself for survival, the same process occurs. In the recall of the event, most individuals having experienced a traumatic event, will state that during the event, things seemed to slow down. The heightened awareness factor and slowing down of events, will only occur if the individual is not over-stressed at the time. If the individual is stressed and is already operating at the heightened level through the increasing stress level, there is no further increased information processing since the mind is already starting to close down as a defence against an overload of information – it is this state in which the pilot does not seem to react as his capacity to process shuts down. This is merely the body's defence mechanism in aiding an individual to deal with the emergency flight situation. The process is not false or a perception, but does occur in reality. Unfortunately, this survival characteristic, which has proved to be so successful in our natural environment, may be the principal cause of delayed decisions, not only in manoeuvring aircraft out of dangerous positions and attitudes, but also making ejection decisions. Pilot's will have been lulled into a false sense of security since this phenomenon is anxiety reducing and the sense of urgency is lost because everything seems to occur in slow motion. The pilot's sense of fear seems to be damped, leading to the pilot believing that the problem can be rectified, that he has the skills required to solve the impending catastrophe.

A USAF survey into temporal distortion found that 86% of aircrew ejectees had experienced the phenomenon during accident sequences. 80% of the respondents reported a slowing down of time while the remaining 20% reported an acceleration in the passage of time. Interestingly, those who reported a slowing down, estimated that the perceived changes ranged from 2:1 to 5:1, a change of 2:1 being the most common.

To overcome the effects of temporal distortion it is obviously necessary for the pilot to understand the existence of the phenomenon and be able to recognise it. This phenomenon is particularly insidious because the sense of urgency is lost and although understanding the phenomenon is one thing, actually making the ejection decision is not. It is imperative that in the airshow sequence planning, besides the 'energy gates', the ejection decision must be made and pre-planned on the ground. A set of criteria must be established for each manoeuvre that defines the boundary of GO/NO GO, to continue or to eject.

There is no time during a low-level display to go into a decision making loop to decide whether to eject or not, to hold on just a few milliseconds to see if the situation doesn't improve. It is during this decision-making process that the aircraft is covering valuable airspace on a collision course with the earth. The pilot cannot and must not wait until faced with the 'last ditch' decision. The course of action must be well planned in advance, during training; there must be no surprises in the low-level display environment. It's a lot easier and faster to simply execute a well thought out decision rather than to have to make a plan and then execute it under acute stress.

ACCIDENT INVESTIGATIONS

Accident investigations should be completed independently by specialists, emotionally uninvolved in the conclusions that are reached. Accident investigations should not be subjected to change by immediate seniors holding agendas that are not in the best interests in aviation safety, no matter the 'big picture' or any alternative strategic agendas that may exist. Senior management should obviously be in the information loop, but by interfering in the investigation or by rejecting the conclusions of specialists on the accident investigation team, a disservice to aviation safety could result in subsequent fatalities. Senior management 'throwing back' the initial findings in fact, by forcing changes to the conclusions and recommendations, prevents the implementation of appropriate corrective actions, thus defeating the primary objectives of accident investigations. Was the case of the *Thunderbirds* four-aircraft crash from a line-abreast loop a case of senior management interference?

Four members of the USAF *Thunderbirds* team were killed in a training accident on 18 January 1982, when four T-38 Talons crashed at Indian Springs AFB, Nevada. The four T-38s were seen to impact the desert from a line-abreast loop. The *Thunderbirds* lost the entire formation team, all four, when Lead's stick apparently jammed as he came down out of a loop and couldn't pull up. Planned entry and exit heights for the loop were 100 ft.

Formation leader was Major Norman Lowrey, aged 37, who had taken over as team leader in October '81 following the death of previous leader, Lt Col David Smith in an accident at Cleveland Airport, Ohio; a birdstrike on takeoff departing Cleveland, he ejected at a very low altitude but his chute malfunctioned which killed him. Number 2 was Capt Willie Mays, 32 and Number 3 was Capt Joseph Peterson, 32, who had both been on the team for two years. Number 4 was Capt Mark Melancon, 31, who had joined the team in October as 'slot man'. The *Thunderbirds* had been under pressure following two fatal crashes in the previous season (including 9 May 1981 at Hill AFB in which one of the team crashed inverted just outside the airfield.)

All in line abreast, the four aircraft impacted within 0.4 seconds of each other in a slightly nose-up attitude when they hit - nothing wrong with any aircraft. The first accident report implied 'pilot error' but the USAF command told the accident team to go back and try again and next time, they came back with the actuator theory, which was published in *Flight International* , 30 January 1982. The report that came out of the crash investigation found that an actuator rod on one of the control services had bent when the pilot pulled the stick harder coming out of a loop. He felt that he was giving it more input, but all it was doing was bending.

In a summary of the accident report that was published in *AvLeak* of 17 May '82, it was reported that that Maj. Lowrey was vastly experienced in fighter operations and as *Thunderbirds* lead, had flown over five hundred loops without previous incident. The throttles of the lead aircraft were reduced well below the settings normally used in a loop, while the engineering analysis of the videotape indicated that the stabilizer angle essentially did not change on the backside until very late and then only by a small amount, far less than the stabilizer design limits. The load relief cylinder in the No. 1 aircraft reportedly showed several indications of failure under tension overload and that Maj. Lowrey was pulling on the stick with both hands at the time of impact.

The accident loop backside conditions were closely duplicated by fixing the stabilizer angle at the 180º point for the remainder of the loop. No absolutely conclusive evidence existed to establish beyond doubt the exact nature and cause of the control difficulties which caused the accident. However, from the weight of available wreckage evidence, the accident loop parameters on the backside and the unusual and inadequate lead aircraft reaction to an increasingly dangerous life-threatening situation, it was concluded that the cause of the crash was technical and not pilot error. Regarding the question as to why the leader had not informed the remainder of the formation on radio as to the impending danger, it was theorised that he had both hands on the control stick during the pull-out. It must be borne in mind that activating the radio on the T-38 would have required taking a hand off the stick because the press-to-talk pushbutton was on the throttle.

For the unenlightened formation aerobatics enthusiasts, the question asked was: "why the remainder of the formation followed the leader into the ground?" Well, quite simply, the other pilots concentrate on the lead aircraft extensively, they probably didn't even see the ground rising up to meet them until it was too late. This is not surprising since if the lead decides to fly into the ground for whatever reason, of course the rest are going to follow him. This is a fact appreciated by all formation aerobatic pilots, faith in the leader is unquestionable. Good formation pilots can't just decide to split up when they start to get close to the ground. The whole principle of formation flying is to always watch the leader and trust him implicitly to know what he is doing and keep the formation out of the dirt.

The report concluded with the observation that between 1953 and January 1982, 18 *Thunderbirds* pilots had been killed (8 in F-100s, 1 in F-105, 2 in F-4s and 7 in T-38s). By comparison, the *Red Arrows* had lost six pilots and eight aircraft (7x Gnats and a Hawk) in the 1965-82 period. The *Thunderbirds* subsequently took a season off, reconstituted and premiered the F-16 in the next season.

The original report being bounced back from HQ to the Board of Inquiry, from political masters to a board of specialists, generally does not bode well for aviation and airshow safety. The overriding of specialist findings by management in any organisation always tends to alert the inquisitive to dig a bit deeper, not necessarily understanding the strategic vision of such strong-handed political decisions. In fact, it is then that the proverbial 'can of worms' is opened and a whole new range of questions are asked.

The accident report stated that power was much reduced, the presumption being that Lead did not want to go beyond manoeuvring airspeed. It is prudent to note that the T-38 is aerodynamically very slick and that the aircraft were in Line Abreast at impact. The theory mooted was that Lead was in such a hurry to pull his power back to put both hands on the stick that he didn't have time to radio his wingmen.

The first question raised by very experienced formation aerobatic team pilots was: "What happens when a leader reduces the power without informing the wingmen? Suddenly you have three new leaders, exactly!. But they weren't in fingertip, echelon or trail, but were already right alongside Lead in Line Abreast. Now, if they were ahead of Lead and pulling even further ahead because of the power advantage, the only way back to the line was to pop the airbrakes. But they didn't do that. So how far over the shoulder does a team member watch Lead until he says: "screw it, I'm outta here! Burner and yank!

Interestingly enough, the film footage doesn't show the wingmen pulling ahead, it shows a normal loop. How does Lead pull the throttle back because of a perceived emergency in a Line Abreast Loop without a radio call and have his guys hang in T-38s at low power settings without boards out? Either Lead made a call or he did not. The Board concluded that he did not. This particular phase of the accident does not seem to have been adequately addressed by the inquiry and left more questions than answers.

It is necessary to consider all the parameters and all the sight pictures. If the flight controls did fault as reported, what else would have happened? If Lead pulled back his throttles because of faulty flight controls, why didn't he make a radio call? If he pulled them back too quickly to make a call, how could the wingmen have stayed in position? If he entered the backside of the loop at too low a power setting, how was it the aircraft's fault? How do you come off the top of a loop (at what-100 knots?) with a "much lower than normal power setting" without one of the wingies calling for Lead to "push it up" as they came down the backside?

There is only one thing that makes any sense - it is not improbable that Lead flew them into the ground. Why is that so difficult to accept? Many solo pilots have been killed performing vertical manoeuvres which in theory, is more difficult to do than when in formation – the formation leader is always aware of his wingmen and with the reduced manoeuvrability of a formation, will not have the liberty of just 'snatching a handful of elevator' to save an 'overcooked' vertical recovery.

Another theory advanced by some high time formation aerobatic pilots that had flown the T-38 was that Lead accidentally pulled into slab stall at the top, inverted at an altitude below target, and as a result, didn't realize he wasn't generating positive nose rate until it was too late. "I never liked the '38 as the choice for a low altitude aerobatic team, especially in the vertical plane. It's just too fuselage loaded to avoid the mush associated with this type of mass distribution. At the top inverted, it's VERY easy to put just a tad too much AOA on the slab tail and cause just enough increase in the drag curve for the tail to go neutral or a bit negative on the nose rate".

In the analysis of 118 airshow accidents in Chapter 3, Man's contribution was a staggering 78%, but considering the unforgiving and hostile environment of the display arena, not unsurprising. Of the 38 FIT accidents, 27 accidents (71%) were in the vertical and 6 (16%) were associated with low-level rolling manoeuvres while the remaining 13% typically resulted from inverted flypasts, flight control systems failures and turning manoeuvres. Makes one think, doesn't it.

Comments by a former *Thunderbirds* pilot addresses some relevant questions that may not have been adequately considered by the Board of Inquiry. "Often, the facts get mixed up with emotions, cover-ups, embellishments and outright stupidity. My experience, I flew the left-wing position for two years in the F-100 and was the Commander/Leader for two years in the T-38. Having said that, I will tell you what I believe and know about the accident in question. When I first heard of the accident and was finally convinced that four aircraft had gone in, I made two predictions. First, it had to be the line abreast loop and second, that the leader hit last. I was correct on both counts. The line abreast loop is the only formation where the other pilots are looking back over their shoulder to maintain the proper sight picture/position. Therefore, they are not able to see anything forward of the flight path, even by scanning forward only with the eyes; with the practice area in the middle of a bowl with irregular terrain all around, even looking through the leader at the horizon gave no clue to the pilots where the bottom was".

"In all the other formation positions, the other pilots can scan the entire instrument panel (check fuel status, airspeed, power setting, etc.) and peep forward to see the ground coming up. It's not that you don't trust the leader, it is just that you become so proficient at what you do, you have the luxury of being able to "peek" on occasion, if you choose to do so. I got to where I could determine the approximate power setting just by the pitch of the engine sound at the upper levels".

"And why did the leader hit last? Because he is the only one who knew they were not going to make it and he made one last attempt to avoid ground impact. It is as simple as all that. Keep in mind that when you are on the back side of a loop at 400 to 425 KIAS, aiming for a 50 to 100 foot bottom, keeping it round while trying to be smooth for the guys in your formation, the only difference between a perfect bottom and a catastrophic one is the snap of a finger in elapsed time".

"It is said that Maj. Lowery was a highly experienced fighter pilot, had many practice loops under his belt, had complete and total situational awareness about him and had all the attributes/qualities of a great leader. All that is true. It is also said by the official report that at the top of the loop, in the float at about 0.5g, a foreign object lodged itself in the artificial feel system, thereby giving Lowery the appropriate feel when he pulled on the stick, but not the stabilator travel commensurate with the feel of the pull. It was so insidious, they say, that Maj. Lowery was not aware of the developing hazard until it was too late to recover. In addition, he hit last because with the impending crash ahead, the rush of adrenaline allowed him to break the stabilator loose and fly a few more feet before impact".

"I could buy that theory if we lived and flew in a one-cue world only. We do not. When you pull back on the stick, a number of clues tell you all is well, or not. The feel of the pressure on the stick, the compressing of your butt in the seat, the nose increasing its track along the ground, the g-meter indicating increased g, the airspeed not increasing too quickly, and so on".

"Can the powers that be have it both ways? On one hand Maj. Lowery was reportedly highly experienced, had complete situational awareness with good leadership skills. On the other, he allowed only one cue to develop into a tragic accident. And why did they all follow? Because even though there may have been some concern with one of the new pilots having a position problem, all else in the manoeuvre was basically assumed to be normal by the other pilots, just prior to impact. I also find it strange, possible, but still strange that the audio of the VCR was inoperative that day. I'll give them the benefit of the doubt".

"The worst scenario I can imagine is that Maj. Lowery would call for the formation to 'go exploded', the term to be used by any pilot in case an emergency develops, where now everyone flies their own airplane and stays clear of the others. He would then eject. At best, the same call would be made, he would recover his aircraft, the mission would be aborted and all would land safely. If the leader loses his radios (a UHF and a VHF) or if there is no transmission from him at the expected times, the No. 2 pilot calls exploded and the show is terminated".

"We did things with the T-38 it was not designed to do. I jokingly tell everyone it was not big, it was not loud, but it was really pretty. It gave us an occasional problem but it never let us down. If I were a wealthy man, I would be flying one today and performing airshows with it. Again, this is my opinion and what I believe really happened. There but for the grace of God go I".

Surviving the airshow circuit is really not that difficult. The display pilot must know the aircraft's capabilities as well as his own. The display pilot must be familiar with the terrain, the winds, temperatures and pressure altitudes. All the numbers required with each manoeuvre: airspeed, altitude, power setting, G's, especially at the tops must be intimately known. If the numbers are not there, the manoeuvre must be aborted – 'all else is rubbish', or so says the Baron. Interpolating can be hazardous to your health.

Understandably, air forces the world over place great pride in their ambassadorial display flying teams; in theory, display teams epitomise the flying skills of that particular air force. However, the pilots are, believe it or not, only human and are subject to making the same mistakes or judgement errors as other pilots. It is just that they spend a high proportion of their time working on ironing out their weaknesses – they use a 'build-up' process – slowly working out the optimum methodology and techniques to fly a given profile and then hours of practice. It is as simple as that. The rejection of the findings of an accident investigation takes a very 'brave' man, especially if such a person has himself never flown as a member of a formation aerobatic team. Worst of all, it becomes impossible to introduce rectification procedures to prevent the occurrence of another accident – the very reason for the existence of accident investigation teams in the first place.

SPECTATOR WITNESSES

Diverting slightly off topic to a not totally unrelated but interesting aspect, is that of the spectator as 'eyewitnesses' to an accident. This topic is relevant since the airshow accident is one aviation event that usually has the highest number of visual witnesses and then of course in modern times, more than adequate video coverage. It is the visual witnessing that is most interesting, if for nothing else because of the unreliability of accounts of accidents. Accident investigations place a high premium on witnesses and video coverage but the credibility of witnesses to airshow accidents, mainly because they happen so quickly and because witnesses are so overwhelmed seeing the catastrophic end of an aircraft, is not high.

At a meeting held by the Flight Standard District Office (FSDO) in Dallas years back to discuss a local V_{mc} stall/spin accident, there was a discussion by the FAA and NTSB regarding accident investigations and the role of spectators as witnesses. It was reportedly stated that pilots make poor eyewitnesses since they tend to have pre-conceived notions of what caused the accident and are not completely objective in what they saw. They said the best eyewitnesses are children, typically between 8-10 years old since it seems they are not yet old enough to have developed biases that affect perception.

The accident investigation into John Derry's fatal accident at Farnborough on 6 September 1952 in the de Havilland DH-110, seems to support this theory. Following his first high-speed pass in which the crowd heard two distinct booms, on his next pass, when Derry arrived over the field, the aircraft disintegrated during an entry into what could at best be described as a climbing roll. The wingtips failed, causing a violent pitch-up that overstressed the airframe; the booms and tail broke away and the aircraft plunged into the spectators. Test pilot, John Derry, his observer Tony Richards and twenty-eight spectators were killed and sixty-three injured.

"He approached the aerodrome again, over Cove Radio Station, and headed directly towards the masses of people on Cove Hill. Over 100,000 pairs of eyes witnessed the disintegration of the aircraft and so it was concluded that the story of the disaster must emerge readily. Each evening, after a day with the wreckage, I read through page after page of witnesses' statements in the hope that some clue might emerge of value to me. These studies would go on until one or two o'clock in the morning. I recollect looking through at least twelve hundred statements and hundreds of photographs, all supported by letters in which witnesses felt certain that they were providing the vital evidence. In the event, when my sequencing was finally completed, it transpired that fewer than a dozen witnesses had told stories that coincided with the now known facts of the disintegration. They all described correctly what they had seen but, by a quirk of circumstance, all those thousands of people saw the accident 'only after it had started' and the few who did get it right, were over near to Cove Radio Station, and nearly under, or to the starboard side of the aircraft as it approached the aerodrome."

"What we had was 100,000 people watching an aircraft that had just made a low pass down the runway and was turning to make another. Most were aware of where he was coming from and were watching for him if they hadn't kept him in sight throughout. The aircraft suddenly disintegrated right in front of them and fewer than twelve people out of 1,200 were to describe the event accurately from the beginning. That's less than 1% of those who submitted statements, and 0.012% of the total that witnessed the accident". ("Air Crash - The Clues In The Wreckage" by Fred Jones - ISBN 0 86379 094 1)

Another accident, not necessarily airshow related, does however, serve to verify the weakness of the spectator as a reliable witness to an airshow accident. The NTSB released the following information on its investigation into the 12 November 2001 crash of American Airlines Flight 587, an Airbus A300-600, in Belle Harbour, New York. The crash resulted in the deaths of all 260 persons aboard and five persons on the ground. The Witness Group received 349 accounts from eyewitnesses, either through direct interviews or through written statements.

An initial summary of those statements follows. "52% specifically reported seeing a fire while the aircraft was in the air, with the fuselage being the most often cited location (22%). Other areas cited as a fire location were the left engine, the right engine or an unspecified engine, and the left wing, the right wing or an unspecified wing. 8% specifically reported seeing an explosion, 20% specifically reported seeing no fire at all; 22% reported observing smoke; 20% reported no smoke. 18% reported observing the aircraft in a right turn; another 18% reported observing the airplane in a left turn. 13% observed the airplane 'wobbling,' 'dipping' or in 'side-to-side' motion. 74% observed the airplane descend. 57% reported seeing 'something' separate from the airplane; 13% reported observing the right wing, left wing or an undefined wing separate while 9% specifically reported observing no parts separate". In the final analysis, it is obvious that the ability of the human to provide accurate recall of airshow accident details, should be treated with caution.

MEDICAL STATUS

During accident investigations, medical examinations occasionally find cases of pilots flying with medical conditions that although not conclusively proven, are reported as possible contributions to the accident through in-flight incapacitation. As an example, a fatal crash occurred on 26 June 1993 at the Concord (NH) International Air Festival. The third afternoon performance was to be a wing walking stunt flight by Ron Shelly and his daughter Karen Shelly from Midland, Virginia. They were flying a PT-17 Stearman bi-plane with pilot Ron in the back seat. The initial portion of the performance was according to script, consisting of a take-off, snap roll, vertical hammerhead and low pass at about 100 ft agl. Both Ron and Karen were seated at this point and Karen was scheduled to climb up on top of the upper wing for a 'wing-walk' later in the show. After completing a left barrel roll, the airplane entered a roll from which it did not recover prior to impacting the terrain.

Mr. Wayne T. Smith, Aviation Safety Inspector (Operations) for the Federal Aviation Administration, was the Inspector-In-Charge for this airshow and he witnessed the accident. In his report, Mr. Smith stated: "I observed the acrobatic performance and accident from the airshow command platform located at the show centre. After the aircraft completed a left slow roll, it entered a left snap roll. I saw the aircraft lose approximately 50 to 75 feet after completing three quarters of the roll. I could see by the acrobatic smoke that the aircraft was skidding to the right. The aircraft continued its left roll as its wings came level about 25 feet above the ground. The nose then came up sharply while the aircraft continued its roll to the left. I could still hear the aircraft engine and it sounded normal to me. The nose of the aircraft continued smoothly in its arc while the wings continued to roll to the left. The nose came down through the horizon striking the ground at about a 60° attitude. The left wing struck the ground almost at the same time and almost immediately thereafter, the aircraft erupted in flames".

The aircraft did not skid from where it impacted but both wings were torn off and the tail portion remained in the impact attitude; the engine was ripped off on impact and twisted back across the cockpit area, now mostly inverted; fire rapidly consumed the forward two-thirds of the aircraft. The fire engine reached the aircraft within a minute but it took several minutes to extinguish enough of the fire to get close to the occupants. Initially spectators thought the airshow would continue after securing the accident, but one by one the acts were cancelled and the airshow was eventually terminated for the day. The airshow on Sunday was repeated and dedicated to the memories of Ron and Karen. The pilot had reportedly told the airshow manager that he wasn't feeling well and was planning to cut short his part of the airshow. This was reported in the Washington Post, which ran it for local interest since the performers were Washington area residents.

Mr. Smith's report also stated: "Earlier that morning, Mr. Ronald G. Shelly, the pilot of N58212, had informed the airshow director, that he did not feel "Up to snuff" and wanted to skip his morning solo acrobatic routine. The airshow director informed me after the accident that Ron Shelly had been complaining about having flu like symptoms four or five days before the accident. On the morning of the accident, I spoke with Mr. Shelly and his daughter during a routine ramp check and spent about fifteen minutes with Ron. During that time he gave no indications of illness nor did he discuss with me the flu like symptoms he had experienced earlier that week.

Mr. Shelly held a Commercial Pilot Certificate, with single and multi-engine, land airplane and instrument ratings. He also held a Second Class Airman Medical Certificate that was issued on February 2, 1993. He possessed a current FAA Form 8710-7, Statement of Aerobatic Competency, dated February 23, 1993. This form was issued after an Airshow Certification Evaluator from the International Council of Airshows, conducted an aerobatic evaluation of Mr. Shelly on February 12, 1993. Mr. Shelly was approved for a Level 1, which involved "No Restrictions" on his performance, including solo acrobatics and his daughter's wing walking. In his application for these ratings, Mr. Shelly reported that he had performed in eight airshows in 1992. His applications for the previous two years also show eight airshow performances. In the "Ground Evaluation Notes" written by the most recent evaluator, it stated: "I've observed Ron at several airshows in the past year and have observed the same safe operations I have consistently seen over the past seven years we've worked together." The National Transportation Safety Board determined the probable cause(s) of this accident as follows. "Loss Of Airplane Control As The Result Of Incapacitation".

Dr. Charles S. Springate II, Chief Deputy Medical Examiner for the Armed Forces Institute of Pathology, submitted a consultation report, in which he stated: "We received the autopsy protocol, preliminary NTSB investigative information, a videotape of the crash and a copy of his outpatient record from the National Naval Medical Center. Comment: "This man's heart disease was certainly severe enough to cause sudden incapacitation at any time. However, there is no way to determine from examination of the heart whether such incapacitation did, in fact, occur". Dr. Charles A. DeJohn, Medical Officer for the Federal Aviation Administration Aircraft Accident Research Section, conducted an Aerospace Medical Consultation for this accident. The report stated: "It appears that a heart attack may be the most likely explanation for this accident. The pilot had a history of a previous myocardial infarction (MI) as well as severe coronary artery disease (CAD)".

"During the week prior to the airshow he was suffering from fatigue and 'flu-like' symptoms, both of which can be symptomatic of heart disease. The abrupt rolling pull-up into unbalanced and eventually uncontrolled flight during the show is consistent with agonal reaction of an individual experiencing the sudden, severe pain of a heart attack. In addition, it appears that for a short period of time during the final phase of flight, the aircraft was wings level long enough for an experienced aerobatic pilot to have salvaged an unintentional manoeuvre and recovered, or at least crash straight ahead to minimize the severity of damage. It does not appear, however, that there was any attempt on the part of the pilot to recover and the aircraft continued its final left spiral into the ground. This suggests that the pilot may have been incapacitated and unable to effect a recovery at the time".

His report continued: "The principal symptoms of heart disease include dyspnea (difficulty breathing) chest pain or discomfort, cough and excess fatigue. The chest pain is often confused with gastrointestinal causes and denial on the part of the patient frequently leads to the conclusion that the constellation of symptoms is due to indigestion, musculo-skeletal aches and pains, or the 'flu'. Evidence suggests the possibility that the in-flight incapacitation of the pilot may have been responsible for the accident. Although the cause of the incapacitation cannot be determined for certain, there are aspects of the history and the videotape that might explain the events: Myocardial infarction, kidney stone, 'flu' symptoms and fatigue. The pilot complained of 'flu-like' symptoms and fatigue for a week prior to the accident. While minor illness, coupled with fatigue have been known to be contributing factors in other airshow accidents, they are usually associated with additional causes such as a stressful schedule causing accumulated loss of sleep (especially the night before), increased alcohol consumption, etc. These elements appear to be lacking here".

He concluded the report with the following: "In view of the variety of data available, a MI appears to be the most likely explanation for the accident but unfortunately, definitive post mortem diagnosis of heart attacks is still only experimental. The 'markers' used in making the determination are not normally obtained at autopsy and the methods are as yet, not well understood. No such information was available in this case and therefore, the conclusions reached must be arrived at by reviewing the medical, pathological, toxicological, video, and accident investigation information".

Gene Littlefield, Chairman of the Safety Standards Steering Committee of the International Council of Airshows, reviewed the accident videotape and consulted with other airshow performers. In his report he stated: "The video coverage seemed to show a poorly executed left snap roll descending to the ground while continuing to turn left. This happened following a nearly perfectly executed left slow roll. In examining the 'stop action' video, the rudder is clearly visible throughout the manoeuvre but it did not deflect to the left at the onset of the manoeuvre as it must, to be a left snap roll. As a matter of fact, the rudder does not deflect in either direction at the onset of the manoeuvre, it stays absolutely neutral".

Mr. Littlefield's report continued: "The rudder is operational in the left direction, however, as the video shows, the aircraft rotates to the left, most likely from "P" factor and torque, then continues rotating left and upon reaching right knife-edge, left rudder comes into play at full deflection. The video shows a number of interesting items for discussion. A very high pitch angle for a snap roll which was most probably attributable to zero rudder input that presented the bottom of the aircraft to the flight path, virtually stopping the forward momentum. The aircraft will eventually rotate left due to 'P-factor' and torque when the lift is accelerated in this manner. The aircraft at this point did a high lift 'half snap' roll to the left and had nearly no forward speed at this point. My aircraft is nearly identical to the aircraft in this accident including four ailerons etc., so I went to a reasonable altitude and tried to duplicate this manoeuvre. I did six repetitions and in every case, if you did make a rudder input, the aircraft would pitch upward to a 70º to 80º angle and then rotate to the left. I tried various speeds from 90 mph to 110 mph and the result was basically the same. I was not able to control the aircraft until I had descended to obtain flying speed. The loss of altitude varied from 200 to 300 feet".

Mr. Littlefield addressed the subject of possible mechanical failure as follows. "I do not believe that this manoeuvre was intended to have been a snap roll in either direction but I believe that the aircraft was pitched upward inadvertently by one of the occupants. Not putting in a rudder upon execution of a snap roll could be compared to leaving the throttle at cruise power on landing. It would not happen; this is instinctive at this experience level. Possible wingwalker entanglement in the controls after the slow roll or possible momentary physical problem with the pilot".

THE QUESTION OF AGE

Questions in the media following an airshow accident often home in on the age of the display pilot. As an example consider newspaper and aviation magazines that open up with: "The 66-year old former British Deputy Chief of Defence Staff, Sir Kenneth Hayr was killed on Saturday 22 June 2002 when the Vampire he was flying at the Biggin Hill Air Fair crashed". Or, "The former *Red Arrows* pilot, 62-year old Ted Girdler from Kent died on 18 August 2000 when his L-29 Delfin jet plunged into the sea of Eastbourne at the annual Airbourne Airshow". Still more disconcerting to read is: "The civilian *"French Connection Airshows"* team of husband and wife Daniel Heligoin (68-years) and Montaine Mallet (52-years) were both tragically killed as a result of a mid-air collision between their two Mudry CAP 10 aircraft".

On the issue of advancing age versus aerobatic demonstration flying, one has to discuss this issue based on a single premise that this line of work involves a specific level of mental and physical performance capability and that this capability absolutely demands an extremely high survival bench mark index. Also, one must consider that this benchmark must not only be maintained, but even increased as aircraft performance and or personal performance parameter limits change with time. This increasing factor has become an even greater part of the equation as advancements in aerobatic aircraft have made manoeuvres possible that were impossible before, such as gyroscopic coupling, etc.

The bottom line is that the subject must be considered against the aerobatic pilot's ability to maintain these extremely high personal benchmarks as a function not of age specifically, but rather as a pilot's individual ability to maintain the high levels of physical and mental aptitude required. In other words, to safely perform in this environment, the display pilot must begin and maintain a physical and mental programme specifically designed to keep within the required parameters demanded by the task...PERIOD! The manner by which a pilot achieves this is a whole subject in itself, involving conditioning and maintaining that conditioning, but as the issue relates to ageing, the approach should be to take age itself out of the equation and instead replace age with an ongoing evaluation that CONSTANTLY CONFIRMS the ability to perform the work involved. This is in fact the basic premise from which all aviation standards are derived.

There are two angles from which to view this subject; the pilot's personal perspective and an outside imposed limits, perspective. The outside perspective, or cut off limit by regulation or other "official" means, is beyond the scope of the book, but from the pilot's perspective, survival in the airshow display environment isn't directly related to age, but is rather directly and unequivocally bonded to the individual pilot's continued ability to perform what's required. This demands a constant ongoing programme of physical and mental fitness absolutely imperative to fly and survive in this profession. Each pilot must be capable of making a completely objective self evaluation of his/her ability to continue with this work based on self imposed NOW physical and mental conditioning parameters. The 'limit' point when safety will become an issue is reached not at a specific age, but rather when this constant self-evaluation tells the pilot that safe parameters can no longer be maintained…..for whatever reason!!!

By making performance instead of age the defining limit of safety, the purpose of safety is better served since it is performance, not age that kills display pilots in this business. That being said, this philosophy is only applicable to those pilots willing to accept these self-imposed parameters. Most who are in this business, or have any experience in this business, are already on such a programme anyway. For those who aren't on such a programme, this brings back the issue of a legal limit based on age, which, is beyond the scope of this book and which, is geared only toward those who wish to fly and survive the display environment.

At the Geneseo, NY airshow in 2002, Oscar Boesch, 80-years old, held an unrestricted (Level One - Surface) ICAS card. He was apparently an ace both ways in WWII, and was still flying airshows. He put on an excellent display and spectators, unaware of his age, would never have guessed that the pilot 'yanking' the aircraft about the sky, was 80-years old. In the final analysis, too little experience and poor pilot judgement, not too much experience, is usually the culprit.

Unfortunately, display pilot experience is NOT transferable. Typical would be a well-heeled airline or military transport pilot with 10,000 hours that jumps into a hot little single-engine aircraft. His 10,000 hours don't count for much, because watching a autopilot fly a 400,000 lb aircraft has little to do with the rapidly-changing visuals, high G and stick-and-rudder flying of low-level aerobatics in a high-performance single. Similarly, you may have someone with decades of experience at flying surface-level aerobatics in a J-3 Cub. If the pilot jumped into an L-39, well, the speeds and manoeuvres radius are much greater, so not all of these hours would transfer, either. In the L-39, the pilot's still very much a beginner and a higher risk until past the crucial initial stage – it is for this reason that ICAS developed the categorized "Level" system, which starts inexperienced airshow pilots at higher altitudes and, as they gain more experience, their minimum altitudes decrease. It's not a perfect system, but for lack of any other scientific mechanism or filtering process, it's the best there currently is at this time.

It's a given that if one considers just the age factor alone without a physical and mental conditioning programme in low-level aerobatics as a linear parameter with a limit that defines the safety cut-off point, that point will be reached at X point in time. One can of course try and determine this point from various source data and perhaps come up with a limit parameter using just the age factor that will serve the interest of safety in general. But, this leaves a wide gap for error that translated into individual's instead of a general overlay, will allow many pilots to slip through the cracks and become victims of accidents that might have been avoided by using a strict ongoing performance self-evaluation along with a physical and mental conditioning programme designed to maintain the extremely high and demanding preconditions required in this work.

By using the performance parameter instead of the age parameter, extends the length of the age linear line for this work. This will maintain a generally safer environment throughout the career of the display pilot doing low-level aerobatics in the demonstration scenario and most importantly, create a safety cut-off limit that could actually save lives.

There is no statistical or scientific evidence to suggest that age should be a limiting factor. As long as a display pilot can demonstrate safety and proficiency with the mental, physical and psychomotor skills required, the pilot should be allowed to do whatever he wants for as long as he wants. However, it needs to be controlled on an individual basis. Comments from one of the pilots of the USAF Heritage Flight: "I know too many older pilots who are doing a hell of a job flying aircraft in every aspect of aviation, including me, I'll be 68 soon and I just spent three days flying with Frank Borman and Bill Anders, both a bit older than me, with their P-51's. A four-ship diamond formation with a '51 as lead, an F-16 on the left wing, an F-15 on the right wing and a '51 in the slot. Also with the jets leading and the props on the wing. There is an A-10 alternating in there as well. It's called "Heritage Flight" sponsored by the USAF. Twelve civilian pilots with their Warbirds, 51's, F-86, P-47, P-38, train with the Air Force and participate in the program. It is very impressive to watch or fly with. They put on about a fifteen-minute routine at airshows (no aerobatics) and they wow the crowds. So I feel very comfortable with that."

SO YOU WANT TO BE A PROFESSIONAL AEROBATIC DISPLAY PILOT?

A career as a pilot is certainly high up on the 'wish-list' of most youngsters, hundreds of thousands annually watching airshows the world over; but only a insignificant percentage of those will achieve their ambitions and dreams – even less will make it at becoming professional display pilots. Within the airshow world, the breed of display pilots flying the aircraft extend from professional display pilots whose job is to display aircraft at airshows for a living, test pilots, military operational pilots, airline pilots, ex-military pilots and aviation enthusiasts with sufficient financing available to afford their own aerobatic or vintage warbird aircraft.

Airshow spectators have watched the display pilots cavorting through the skies, each manoeuvre appearing to be a private torture chamber for the pilots as they pull high positive and negative 'g' loads during their manoeuvres. They seem to blissfully take their aircraft through gut-twisting manoeuvres that amaze the non-aviators and skilled pilots alike. Though most people probably wouldn't admit it, they often experience esoteric thrills as they watch the aircraft and pilots seemingly defy the laws of physics, or when they feel the rumble and raw power of an afterburner cutting the air apart.

So what's it like to be a professional show pilot? What type of lifestyle is it? Is it possible to make a living from such a career and what training is required? To answer that question it is appropriate to consider a case of just such a pilot that flies aerobatics for a living. Michael Mancusso, one of the top rung airshow performers in the United States does just that, display flying as a career. Michael was a member of the *Northern Lights* Aerobatics Team for a number of seasons but turned to solo flying an Extra 300L sponsored by Klein Tools. The Extra 300L is an unlimited aerobatic, high-performance, mid-wing, 300 horsepower, tandem seat aircraft. Possessing a roll rate in excess of 340°/second, a climb rate of approximately 3,200 feet per minute and a certified load factor of +/-10 Gs, the Extra 300L has the potential to demonstrate a spectacular range of aerobatic manoeuvres. The visibility is superb; it's like you're sitting on top of the plane, so the combination of high performance and excellent handling qualities makes it an exciting job to provide the maximum aesthetic appeal to the spectators.

A typical show for display pilot Michael, in this case at a military base, starts with an arrival at the Base on Wednesday. He conducts sponsor, media and practice flights on Thursday, and then tries to get in some additional aerobatic practice. On Fridays, he flies a closed show for school groups, military families, VIPs, etc., and then the open show on Saturday and Sunday for the general public. Each day starts with a compulsory 8.00 am briefing - you're not allowed to fly unless you have attended that briefing. He'll try to fly a minimum of one practice session each day whenever he can get a low altitude waiver box. Usually he gets to practice in the airshow area at least three to five times before the weekend. Mixed in with all the flying, is the need to keep the aircraft operating in top shape, plus various interviews, autograph sessions and airshow social events, making show days pretty long at times.

In between the different shows, he has to ferry his aircraft and equipment to the next show where he starts the routine all over again. Some pilots let their crew chief ferry the aircraft to the next show, while they take a commercial airline. How the aircraft, equipment and crews get from show to show is primarily based on how far away the next show is and how much time they have between shows. In Michael's case, his crew chief and personal assistant is a savvy and very pretty lady named Holly Ropp. One of the ways they cut expenses is to put all of their equipment in the front seat of his aircraft, which he ferries to the next show, while Holly flies commercially. This works for them because Holly also happens to be a commercial flight attendant. She has a very flexible schedule in which she flies ten days a month and then spends the rest of the time crewing for Michael. While some crews carry technicians with them, whenever the need arises, Michael just uses the local aviation mechanics wherever he is located.

In case you're wondering, airshow flying isn't entirely stress free. If you're going to do it, you'll need to be willing to endure the stress of flying several high '6g' airshow routines per week, plus give several sponsor and media rides, make public speeches (which, for some, is more stressful than aerobatic flying), sign autographs, attend aviation socials until late in the evening, and then get up early and start all over again. You've also got to live in a circumspect way so that you don't do or say anything that might embarrass your Sponsor.

Somewhere in-between all that, you have to take care of the bills, administration, communicate with future event coordinators, schedule maintenance and a myriad of other logistical things like ferrying your aircraft to the next destination. Remember, you're going to be 'on the road' most of that time - days off may not occur unless you're intermittently booked or fairly close to your next show location. You also need to be willing to work out to stay in shape, discipline your diet to keep your weight down, and live out of your suitcase for about nine months (March – November, the airshow season in the northern Hemisphere) each year. But the performers say they love it! And if you're doing what you love, it isn't a burden or a chore, it's always a joy. Besides, if you can't sing, where else can you go to work for yourself, be applauded by thousands of people, be written about in magazines, appear on television, travel and see the country, sign autographs, have your own fan club, all the while doing what you enjoy? During the off-season (December – February), Michael manages the family business, the Mid Island Flying School, and teaches in his aerobatic school, Gyroscopic Obsessions, both located in Long Island, N.Y.

So how does one become an airshow pilot? Well, if one has not passed through a military flying training programme, after obtaining a private pilots license and building up hours (a necessary step on the road to airshow flying), you can get started in aerobatics by going through a step process of training. A good way to begin that training is to join an aerobatics club such as the International Aerobatics Club (IAC: http://www.iac.org). Under their guidance and tuition, you can learn about everything from recreational aerobatics to competition aerobatics. When you start your training, the levels of training you will proceed through are Basic, Sportsman, Intermediate, Advanced and Unlimited. The first three levels are relatively inexpensive to learn but the higher categories are more expensive because it takes a special aircraft and a much more experienced pilot to instruct you.

If all you are interested in is recreational aerobatics, you only need to progress through the first three categories. But if you are already an experienced aerobatic pilot and you're interested in competition aerobatics, it is recommended that one also talk to some of the top rate airshow performers since many of them provide personal instruction as a sideline. To become one of the best, why not learn from someone who is already walking in those shoes? Just find one that is based near you and contact him/her during their off-season.

Once you become proficient and somewhat experienced in aerobatic flying, the advanced instructor can help you become an unlimited airshow pilot and show you how to put together an airshow routine. You'll need to put together at least two routines: one that lasts about six minutes (added attraction), and another one that lasts about twelve minutes (main attraction). An instructor will also help you develop the ability to fly safely at minimum altitudes. It's not as easy as it looks but you don't get to make any mistakes when flying inverted, ten feet off the ground.

Simultaneously with starting your advanced aerobatic training, you'll also want to join the International Council Of Airshows (ICAS: http://www.airshows.org). These people know everything you'll ever want to know about being a professional airshow pilot (and probably some things you don't want to know). How do you afford the aircraft? Don't start with an Unlimited Category aircraft like the Extra, rather start with something practical like an aerobatic certified Cessna 150. Then move up in aircraft capability as your proficiency increases. That way, if you decide that being an airshow pilot isn't really your cup of tea, you're not stuck with an aircraft that has a limited market. Having your own 'g' capable aircraft is the least expensive way to develop your skills. If you don't have a primary source of funding that will allow you to make step purchases of used aircraft in the $30,000 to $200,000 range, then it is suggested that one forms a partnership with two or three other people. Talk to an attorney and tax advisor and look into the possibility of forming a limited liability business partnership with equal shares of stock. Owning a share of an aerobatic act with occasional crewing responsibilities, might be very attractive to some people.

How do you enter the Airshow Arena? Firstly, start out by doing local airshows, flying within your capabilities and certification. Don't be afraid to fly for 'free' until you get enough shows under your belt to create a small résumé. Continue your training so that you can fly at increasingly lower altitudes and with greater expertise. As you move further away from your home base, seek out regional sponsors. That way, some, or all of your airshow expenses will be covered. If you live in the USA in California, Texas or Florida, you may be able to make a decent living by just flying the numerous airshows within your own region. Your goal must be to gain sufficient experience in aerobatic contests and small airshows to make the leap into the professional airshow industry on a full-time basis. The fact that you will have developed a "sponsorship history" will be useful when you start looking for a national sponsor. Once you become certified and gain some experience in the unlimited category, you may be ready to branch out nationally.

Can you make a decent living at it? Being a professional airshow pilot is a lot like being a professional golfer. You must earn enough money during the nine-month golf season to support yourself for all twelve months. But, one is not prevented from doing something else to earn additional income during those slack three months. Expense-wise, things start to get a little easier once you start performing at airshows. Traditionally, the airshow host is responsible for providing accommodation for the crew, personal transportation for the team, hangarage and service facilities at the airport, servicing and maintenance assistance, petroleum, oil, lubrication and smoke oil for the show aircraft. After expenses, you should be able to earn at least $30,000 per year.

Some actually earn over $100,000 a year. It obviously depends on how much crowd appeal or attraction the display is, and whether you're one of the main acts or not. It also depends on whether you have a main sponsor. Do you have additional small sponsors on top of that? Do you have merchandise for sale (pictures, books, hats, t-shirts, cups, etc). Is your act so impressive that people will drive 30 miles across town and stand in the hot sun to watch your show? The money is in the theatre you provide. [David Juwell, Michael Mancuso and Klein Tools, FMI: www.mmairshows.com.

Try to get a local company to become your main sponsor and add several small sponsors too. (Michael Mancuso)

SPONSORSHIPS OF PERFORMERS AND AIRSHOWS

The key to a successful sponsor request is to focus on the benefits for the sponsors, not to tell the company what you need, but what they will gain from working with you. Before you approach a company do your own homework. Learn to know your own product, either airshow or aircraft, and know what it represents. Not a single company is interested in idle promises or wrong figures. Check your project with these questions:

- How big is your audience; what is their professional breakdown, what are their ages, revenue, male, female, and children. What is your media return?

- What return can you guarantee to your sponsor. Brochures, posters, advertising, written press, magazines, TV and radio, website, media partnership for the event or aircraft. Any reports announcing your event, venue or aircraft. Articles in the press, reports in TV-journals etc?

- How original are you and what are those values associated with your project? Are you a one of a kind? The best? Are you the only airshow in the vicinity?

Is there someone within your project who is closely involved in a major company, a board member, a director? Can they help with the introductions? It is always best to work from a recommendation! If you don't have any, show yourself! Make yourself known together with your potential prospects. If you know your project well, make a list of all the things you have to offer. BE CREATIVE! You have a lot more to offer than the traditional 'return of investment'. The sponsor's name associated with the event, VIP tent + VIP passes and VIP parking, Logo's on the posters, brochures.

There are many other ways: from the entrance ticket to the trash boxes, toilet and event signs. Try an interactive offer with a competitive element, where your audience can participate. Try the angle of the 'business incentive', the corporate 'day-out'. Many companies still spend small fortunes on incentive days. Combine it with good food, a ride in a sports plane at the end of the show, an informal meeting with the pilots, etc. Other mass-events have been doing this for a long time, just think about the business seats in a football stadium…

Once you know your product well, you can determine your realistic market price and pricing policy but just remember that display flying is not Formula 1, so we will not get Formula 1 budgets. Just like in any other industry you have to be competitive, innovative and seductive. Don't forget that the target of your sponsor hunt is to increase their prospect of sales so help develop their business.

NEVER approach your potential sponsors without first doing your own proper homework. Don't kill a good opportunity due to a lack of professionalism. Hunting for sponsors is very similar to a war game: You need your intelligence to build a successful strategy! Now that you know your own product, you have to learn the same things about the products of your prospective sponsor. Who are their typical customers, are they similar to your audience? Are they planning to launch a new product? What are the revenues of the company but keep your proposal in perspective.

WHO has the power? – remember that most people in a company have the power to say no, only few have the authority to say YES. When you have been through all these steps, you are ready to approach your prospective sponsor. How? Anything can work; if you mail, phone and send in paperwork, make sure you have a sparkling presentation ready. Vibrant, easy to read, visual, to the point!

What works best is to generate your own invitation by recommendation from someone within the company, so make yourself known to the company! The worst thing that can happen is that the person you have to negotiate with has never heard about you or your projects. Always be positive and enthusiastic; if you cannot 'breath' your project you will not be able to give the sponsor the same spark!

(*Jacques Bothelin - Director, Apache Aviation and Leader of the Khalifa Jet Team. Jacques is an active display pilot and currently operates the biggest sponsor budget in aerobatic operations.*

Tom Poberezny voiced some concerns about the next generation of airshow pilots and the increasingly competitive environment they will fly in. “The better pilots are those who can execute professionally with the highest level of precision and still be entertaining,” he said. “They don’t have to fly the lowest or on the edge all the time, because they’re more creative.... Today we live in a marketing society, and it seems that people who depend on the public spotlight have to be controversial or flashy to make an impact or just to stay where they are. I have the feeling that the airshow business is going more that way. A lot of people are trying to get in and make as big an impact as possible, and they’re not going to wait 15 or 20 years - they just go buy an airplane and want to be a top professional quick.”

CHAPTER 6

DISPLAY FLYING SAFETY DYNAMICS

“The display pilot must know the overall design capability of the aircraft and recognise his own limitations and avoid exceeding either”. (Bob Hoover – Test Pilot and International Airshow Display Veteran)

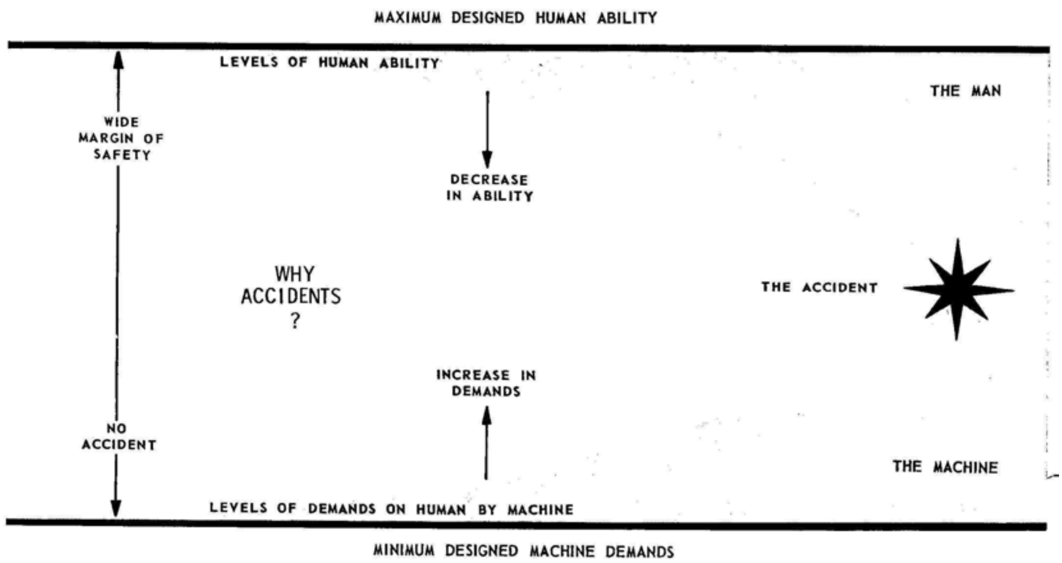
INTRODUCTION

Any display involves a pilot on the one hand and an aircraft on the other, each with its own set of capabilities and limitations. For a safe and successful performance, the display must be conducted within each one's limitations. The professional display pilot must know and understand not only his own limitations but must also understand the limitations of the aircraft and the effect of environmental factors on the performance of the aircraft. Most importantly, the display pilot must understand the dynamics involved in manoeuvring an aircraft in close proximity to the ground and to other aircraft.

From the analysis in Chapter 3, it was concluded that approximately 79% of airshow accident's causal factors could be attributed to MAN; the remaining 21% being constituted by MACHINE (17%) and MEDIUM (4%). In most cases, the pilot has no direct control over mechanical failures or over Medium's environmental effects such as density altitude, cloud base, visibility, crosswinds, etc. In theory, therefore, the term 'Pilot Error' cannot be ascribed to the accident categories of MACHINE. But even if the pilot has no direct control over the elements, it remains prudent to convert the display to a bad weather sequence or even cancel the flight if the weather conditions are not optimal for the designed sequence.

In considering MEDIUM, although it may not be semantically correct to assign the term 'Pilot Error', MAN can certainly can be held indirectly responsible in cases in which the pilot elects to conduct and continue manoeuvring under conditions of adverse weather in which the probability of an accident or judgement error is increased.

The decision to change from the good weather display sequence to the bad weather sequence is a pilot's decision, not the Airshow Organiser's or the Display Safety Committee's. The criteria for changing the display from good to bad weather routines, from the vertical to the horizontal, looping to rolling or even cancellation, must be defined prior to



Graphic representation of the relationship between MAN and MACHINE causal factors. (USAF Flying Safety Magazine, "The Slow Speed Demon" by Dr A. F. Zeller)

the airshow. However, should the Display Safety Committee call for the move from good weather to bad weather sequence, the professional display pilot should adhere to the call. Most airshow organisers will try to continue the airshow in the face of adverse weather, the concern being mainly economic of course.

MAN's inherent physiological deficiencies are directly responsible for the 79% contribution and are manifested by the categories of Flight-Into-Terrain (31%), Mid-Air Collisions (25%), Loss-of-Control (20%) and Wheels-Up-Landings (3%). MAN cannot escape the responsibility for loss-of-control accident causal factors which are typically attributable to poor aircraft handling techniques, poor anticipation, poor situational awareness, poor judgement and slow pilot response or reaction times. Of the thirty-eight FIT accidents identified in the analysis, twenty-seven accidents (71%) were in the vertical and six (16%) were associated with low-level rolling manoeuvres while the remaining 13% typically resulted from inverted flypasts, flight control systems failures and turning manoeuvres.

Knowing and understanding the overall capabilities and limitations of the aircraft should begin with a thorough analysis of the aircraft's performance and handling qualities. Knowledge of take-off and landing performance, both low and high speed manoeuvring limitations, energy management under the prevailing density altitude conditions, roll performance in the various configurations, turn radius and time to turn for various airspeeds, closing speeds and recovery pullout heights for various dive angles, is typically the essential information required prior to compiling the show routine. What factors control these dynamics and how do they affect the manoeuvres? Where are the traps and what should a pilot understand regarding these factors?

Within the realm of low-level display flying, there are certain specific dynamics that are particular to safety of flight and which have bearing on the human physiology and the physics involved in display flying. Factors include closing speed, energy management, display volume, inertia and momentum, pitot/statics, density altitude, mass and centre of gravity, turn performance, roll coupling, structural loads, departure and spinning considerations and emergency abandonment amongst many others – all readily tangible. The intangibles on the other hand are two critically important unknown variables, the state of mind of the pilot, which may vary from minute to minute, and the associated decision-making processes of the mind.

CLOSING SPEED

At the expense of melodrama, cemeteries the world over contain the graves or memorials to pilots that have been killed doing low-level aerobatics. Of course there are those that have been fortunate enough to escape death, but not necessarily injury. The most classic and well-known example must surely be Battle of Britain ace Douglas Bader, who crashed in 1931 doing a low-level 'slow roll' overhead the airfield in a Bristol Bulldog - and as the saying goes, the rest is history.

This might have been placed in the don't do it again category, except for the fact that many other pilots have before then, and since then, had similar experiences but, in most cases, managed to complete the low-level roll or recover from the low-level vertical manoeuvre with a few feet to spare – a few feet less and the results could have been disastrous. The fact that they did not impact the ground being rather more by divine intervention than any 'superb piloting skills'.

With the aim of the pilot being to level-off from a specific vertical manoeuvre at heights of between 100 ft to 200 ft, display pilots could do well to consider dive angles, descent rates and closing speed toward the ground during each of the manoeuvres. They would be very surprised to find out that in some cases in a high speed military jet for instance, on passing through the 270° position in the loop or in a vertical dive, the aircraft could have an instantaneous rate of descent in excess of 500 feet per second (30,000 ft/min). In theory, if the pull-out was delayed by as little as 0.02 seconds (1/50th secs) or more, well…let the math do the rest.

High closing speeds in excess of 1,000 feet per second are not uncommon during synchronised opposing manoeuvres which place a premium on the pilot's reaction time, anticipation and situational awareness. The multiple formation permutation being particularly difficult to get to the crossover point simultaneously. *(Reproduced by kind permission of Robert Stetter www.robert-stetter.de)*

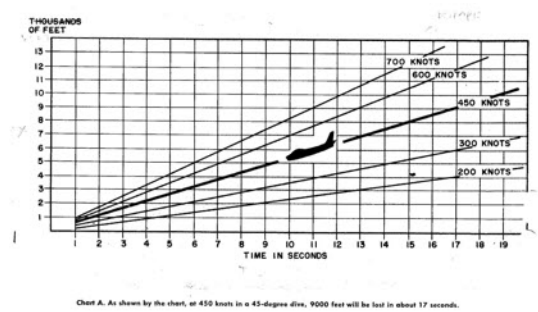
There is no doubt that pilots aggressively attempt to complete the manoeuvre perfectly and not to write themselves off or generate mass hysteria amongst the spectators or the Display Safety Committee members. Inadvertent near misses would be reduced if pilots realised the criticality of two particular factors, both of which every display pilot must know, understand and ultimately, respect. These two factors are first the terrific, almost unreal rate of closing speeds in any vertically descending manoeuvre, and secondly, the built-in limitations of man's reactions which are appallingly slow when pitted against the rapidity of events that may be encountered in high-speed, head-on, opposition or closing manoeuvres.

High closing speeds are something rather new to the human physiology. To previous generations it never meant much more than an occasional collision between two cars, crumpled bumpers and a ruffled disposition was the price to pay. To a driver of the modern car, however, we have begun to learn more about closing speeds and to develop a respect for it. The relative ease with which man has learnt to compensate for this new challenge is somewhat of a tribute to his ingenuity and our ability to learn to compensate within a dynamic environment. Within a very few years we have learned to glance at oncoming traffic and decide with a certain degree of accuracy, to safely overtake the vehicle in front. Subconsciously we have developed a third dimension gauge of this relatively new phenomenon although some of the more unsuccessful cases of failed compensation regularly fill the obituary columns of newspapers.

Yet, in spite of our experience on the highways, when we fly an aircraft, we encounter closing speeds for which there is no terrestrial comparison. The lack of peripheral cues in flight against which to assess airspeed, makes it extremely difficult for the pilot's brain to assess rate information. While driving a car, the road, ambient noise level, passing trees, hills and other surrounding features makes it possible for the driver to perceive and process relative speed. In flight, we have as yet, not been able to fully comprehend and estimate the phenomenon of high closing speeds at a glance with any accuracy. It is necessary therefore, to take a look at the geometry and the dynamics involved in closing-speed as one of the primary survival cornerstones of low-level display flying.

By way of an example, consider the backside of a loop as characterising other vertical manoeuvres such as the hammerhead-stall and tailslide - we need to understand the time-space geometry of the downline vertical manoeuvre. There are just three factors in it, dive-angle, airspeed and recovery height. The first factor, angle, is a simple concept in a vertical manoeuvre such as a loop in that once the aircraft has passed the apex of the of the vertical manoeuvre inverted, and is pointed 45° below the horizon, it is committed.

The second factor is airspeed, another simple concept, but the higher the airspeed, the more critical the contribution of the airspeed factor in affecting a safe recovery pull-out. Now the combination of these two factors, angle and airspeed, if not in the correct relationship, could result in catastrophe. The correct balance is vital because basically, if the angle is down and the aircraft has airspeed, a collision with the ground is inevitable if no effort is made to change the angle. Therefore, in any profile where speed toward the earth is established, there must be an accompanying and equally important consideration, time. Not knowing the minimum length of time that the airspeed and angle may be maintained before change is essential, is equivalent to 'not knowing that the gun was loaded'. There are several charts that illustrate how long it takes to lose height in various dive angles versus airspeeds.



Dive time versus altitude chart. *(USAF Flying Safety Magazine "Short Seconds" by Col H.G. Moseley.)*

A simple example is illustrated in the accompanying chart. In this profile, to start from 10,000 ft and pull out from the dive at

1,000 ft requires 9,000 ft for the descent. As can be seen from the chart, at 450 knots, it will take 17 seconds to descend the 9,000 feet in a 45º dive. However, if the dive is maintained for exactly 17 seconds, one more unforgivable error will be committed – that is the error of allowing insufficient time for the recovery pullout.

Recovery is the last major factor in the relatively simple geometry of a dive. However, take a long careful look at this aspect because the recovery pullout from a vertical manoeuvre brings into sharp focus the most critical hazard of closing speed. Scientists have produced long dissertations concerning acceleration, G-force and other physical laws of time, motion and space that are involved in changing the airspeed and direction of flight. But the factor that directly confronts us in recovering from the dive, is Momentum. One of the peculiarities of nature is that when an object is moving, it keeps right on moving in a straight line until it meets some form of resistance. The heavier the object and the faster the speed, the more resistance it takes to slow it, turn it, or stop it.

This tendency to keep on going is due to the object's momentum, derived from its mass and velocity. A baseball, after being pitched, continues in the direction it is thrown due to its momentum, and it is stopped by the resistance of the batter, the catcher, the solid earth or the friction of the air. If a rock the size of a basketball is thrown with any force, neither the bat nor the catcher can stop it effectively and it will take considerable friction to overcome its momentum.

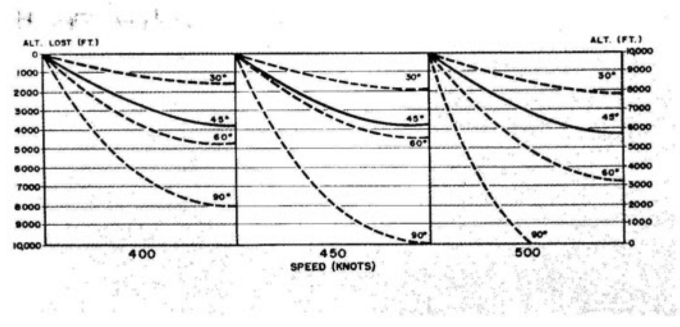
This tendency to resist change in the state of motion is described as 'Inertia' which is essentially the resistance an object has to a change in its state of motion. 'Moment of Inertia' is the term given to describe rotational inertia, particularly relevant in aircraft manoeuvres involving rolling, pitching or yawing and then of course angular accelerations about each aircraft's axis. Fortunately, momentum is a direct and linear function of Mass and Velocity. One can only begin to imagine the effect of momentum on display flying if velocity was a square or cubed function. Mathematically, therefore, momentum 'p' is:

$$p = mv$$

where
m = mass
v = velocity

In the case of an aircraft, several streamlined tons of machinery at high speed creates an awesome amount of momentum that requires an equally awesome amount of resistance to change. Consider an aircraft in a 45º dive, the only form of resistance available, albeit relatively insignificant, is the friction of air. With this drag, the aircraft must be decelerated and the pilot must change the direction of the aircraft by at least 45º. A speed of 450 knots is considerable, and a jet aircraft, even with airbrakes extended, does not offer much surface for effective air resistance. Therefore, the aircraft requires both time and distance to overcome speed.

In fact, so much time and distance is required to slow down a dive that a reduction of speed is only of minor significance in the problem of recovery. What is of paramount importance is a change of direction, the toughest challenge of all. It is something that every display pilot is constantly confronted with and it is also closely tied to the fundamental laws of nature and must be given the greatest respect if display flying is to be safe and successful.

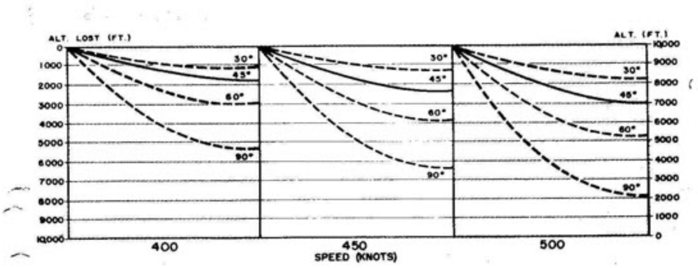


Height lost during 4g Pull-out at 450 kts.

Because momentum tends to keep an object going at the same speed and in the same direction until it meets resistance, when the aircraft's nose is pulled up to change the dive angle, G-forces are created. The more rapidly the direction is changed, the greater the physical force exerted on the pilot and the aircraft. If excessive force is applied by the pilot, unconsciousness or catastrophic structural failure may occur.

The two charts illustrate the height lost in pull-outs at different dive angles from 10,000 ft at 4g and 6g. It is instructive to consider the height lost to pull out of a 45º dive at 450 knots at 4g and 6g; 3,800 feet versus 2,200 feet, respectively.

As an extreme example, in a 90° dive at 400 knots, the height lost in the recovery pull-out at 4g is 8,000 feet reducing to 5,300 feet at 6g. However, the amount of ‘g’ that can be used effectively on the aircraft and the time required to recover at a particular speed for each specific manoeuvre, must be known by the display pilot well in advance. If insufficient time is allowed at too low an altitude before recovery is initiated, momentum and inertia, following the inexorable laws of nature, will take over and commit the aircraft to structural disintegration in the air or collision with the earth, no matter what physical effort the pilot applies. With approximately 71% of the Flight-into-Terrain airshow accidents occurring in the vertical, the criticality of momentum versus height in vertical manoeuvres is substantiated.



Height lost during 6g Pull-out at 450 kts. (USAF Flying Safety Magazine “Short Seconds” by Col H.G. Moseley.)

The amount of height needed for the recovery dive from all manoeuvres must be carefully computed and actually measured during the in-flight build-up training because it is least subject to compromise. This altitude must then be added to the height above the surface at which level flight or the recovery pullout height is required. Besides pulling-out at a safe height, the display pilot will continuously be making gross manoeuvres and finer corrections to maintain the showline.

Unfortunately, input cues for the display pilot to control the recovery dive are few, the pressure altimeter and pilot’s peripheral vision are the main sources of absolute altitude and rate information. Use of the altimeter only, is not reliable since the ground and the altimeter cannot both simultaneously be monitored and at high rates of descent and steep recovery pullouts, the altimeter is subject to ‘lag errors’ placing the aircraft many hundreds of feet nearer the ground than is indicated on the instrument. The pilot thus uses a compromise of altimeter and vision, understanding the shortcomings of the pressure altimeter under highly dynamic manoeuvring conditions. Although more accurate, a radio altimeter is usually not fitted to warbirds or aerobatic aircraft but equip most military aircraft. However, the radio altimeter is unreliable and not useable with any confidence at pitch/roll attitudes greater than 30º due to ‘break-lock’ of the radio signal. For those who wonder why vision alone is not a good substitute for controlling the dive and recovery, it is well to consider the physiological limitations of man and his reaction time.

There are other limitations of the visual system which are of importance to the display pilot. For example, when the pilot looks into the cockpit, looks outside and then refocuses his sight on the instrument panel, it takes approximately one second. Scanning of the instrument panel is also time-consuming – a lateral movement of the eye of 20º will take approximately five-hundredths of a second – even parts of a second are critical at rates of descent of 200 to 500 feet per second.

Consider the intriguing case of the USAF *Thunderbirds* T-38 Talons four-ship formation crash in the Nevada Desert in 1982. At the time that the Leader of the formation recognized that he was not going to be able to complete the recovery from the loop, the formation had entered an inverted attitude from which safe recovery was impossible. What that means is that once a specific nose-down pitch attitude is obtained, a required minimum altitude is necessary to achieve a safe recovery pull out. In theory, for a single aircraft with high manoeuvrability, the angle is 45º but, but for a less manoeuvrable four-ship formation, this angle is estimated to be closer to 40º.

A call for 'breakout' anytime after about 40º nose-low, inverted in the formation loop, would not have helped. With that said, it must be realized that in all probability, the Leader didn't realize he had lost it until he was at, or past, the ninety-degrees down point. If lead was having trouble pulling out of the loop as the official accident investigation report concluded, couldn't he then call for the rest of the aircraft to break out of formation and save themselves?

Well, the leader was presented with an insidious situation. He apparently did call to his wingmen; at 270º, he realised he was a bit low and fast and called for "a little more pull, and back on the throttle". He was reportedly still well within the envelope to pull the team out but there was no response due to a flight control problem. At this point he was less than six seconds from impact and would have begun pulling the stick with both hands and at about 310º he apparently got some response, but not enough. There were no more radio calls and actually, at that point, even if maximum response was achieved, the formation would still have crashed.

It is only natural that in a life-threatening situation, survival becomes the pilot's only focus, mentally saturated making continuous estimations of the height versus airspeed versus pitch attitude. The pilot's mind is continuously transferring the geometrical analysis through to the control stick, and verging on the edge of panic! That's how it is!

Airshow accident examples of high closure rate are many. It is relevant to recall the *Frecce Tricolori* mid-air collision at Ramstein in 1988, the head-on collision between the *Red Arrows* synchro-pair in 1971 while performing a 'Carousel', and the two *Blue Angels* pilots that collided head-on during an opposition roll in 1985 are some of the better documented examples. Did the pilots realise exactly what the odds were that were stacked up against them when they set-up for the crossing-passes? What were the causal factors?

In the case of the Italian Air Force singleton pilot, he was certainly aware of the timing criticality and the risks involved – in fact, he was reportedly having problems during the practice session getting the timing right. Consider the difficulty of getting two formations, one of five and one of four aircraft opposing each with a closing speed of at least 1,000 ft/second, crossed over the by singleton, all at the same time and abeam of show centre – no easy co-ordination task. The *Red Arrows* synchro-pair pilots would certainly have known that head-on passes create formidable closing speeds; for example, if both aircraft were flying at an average airspeed of 350 KTAS, this would produce a 700 KTAS (1182 feet/360 meters per second) closing speed. The rest is a story of human reaction time.

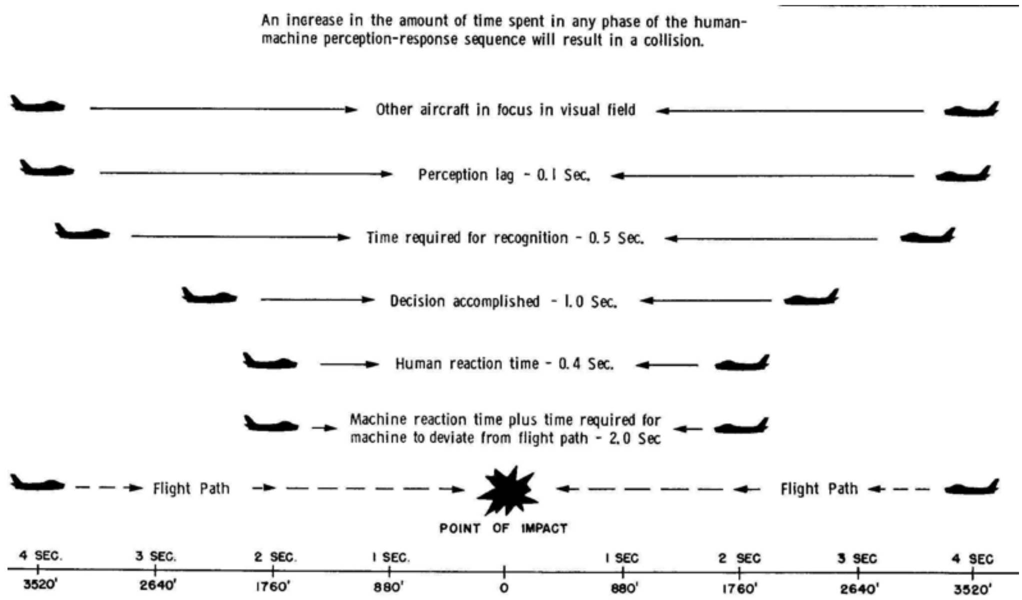
In considering man's reactions when confronted with such high closing speeds, the first problem is one of visibility or vision, or better yet, the ability to visually acquire the approaching aircraft at low-level as early as possible. Even on a perfectly clear day, it is difficult to see an approaching aircraft until it is quite close. The greatest distance at which a large aircraft can be seen approaching directly head-on is approximately seven nautical miles but for a generic type fighter, this reduces to a little over five nautical miles. The probability of seeing an aircraft at greater distances is not high and it is for this reason that many formations use 'smoke-on' at an early stage of the head-on run-in to enable earlier visual identification.

As an example, assuming that both pilots closing head-on under excellent ambient visibility conditions had a 'tally' on each other at five nautical miles and were completely aware of each other's position, they would effectively each be two and a half nautical miles (15,190 ft) away from the crossover point. The more probable 'real world' scenario with haze and smoke would in all likelihood cut this 'tally' distance down to between three and four miles.

However, for the sake of the argument, closing at approximately 1,182 feet per second, each pilot would then have 12.9 seconds in which to align the aircraft before the crossover. This may sound like a relatively long time, but if for whatever reason there is any decision making that must occur due to uncertainty of being on the correct side of the runway for the pass, or a delayed visual identification due to residual smoke in the show-arena, then the seconds are what can at best be described as 'short seconds'. It is here that an uncompromising factor called 'time lag' becomes the 'killer'.

So what does 'time lag' imply? For the sake of the argument, it takes approximately 0.1 seconds for the nerves to carry what the eye sees to the brain and for a well practiced display pilot, approximately 1 second for the brain to recognise and process what it sees . To make a multiple–choice decision, it then takes approximately three seconds for the brain to decide whether to turn the aircraft left or right and/or to push up or down. Approximately 0.4 seconds is required for the nervous system to transfer that decision to the muscles and command them to move.

In a conventionally designed flight control system, not a fly-by-wire, reduced static stability aircraft, it then takes another approximately 1.0 second for the aircraft to displace



Schematic diagram illustrating closing speed and the MAN-MACHINE perception response sequence for two aircraft head-on at 521 KTAS (600 mph). (USAF Flying Safety Magazine, "The Slow Speed Demon" by Dr A. F. Zeller)

itself from its trajectory because time is required for the controls to move, the airflow to deflect, and most critically, it takes time to change the tons of aircraft momentum from its course. By way of example of the effects of momentum, if an aircraft were accelerated at a rate of 1g per 0.1 second for 0.5 seconds, 5g would be generated on the aircraft. During this time, the aircraft would have deviated less than 10 feet from its trajectory. Therefore, in the example under consideration, a total period of approximately 5.5 seconds is typically required to introduce gross manoeuvring changes.

What does this time lag mean to the two display pilots in real terms? It means that 118 feet is covered in the 0.1 second for sight to reach the brain. It means that 1,182 feet are covered in the one second for recognition to take place plus 3,546 feet in the three seconds for the pilot to decide how to make the gross and fine corrections of the line-up. It means 473 feet is covered in the 0.4 seconds for the pilot to react and another 1182 feet for the aircraft trajectory to begin to change. All in all, 6,437 feet is required from the time of visual acquisition, to the time the aircraft are lined up coarsely, leaving only 7.4 seconds (approximately 0.72 nautical miles) under ideal conditions to make finer tracking corrections if required. Unfortunately, parallax error over long distances does not allow even the well-practiced pilot to always get it right first time and in the real world, there is usually always a requirement for a further set of smaller corrections.

In the case of the *Frecce Tricolori* singleton and the *Red Arrow's* and *Blue Angel's* synchro-pairs, time ran out for decision making; set-up conditions were far less than ideal, less than perfect alignment or delayed visual acquisition by only a few seconds, increasing the probability of a head-on collision. These cases serve to emphasise the dynamics of the problem, the severity of which increases dramatically with increase in closing speed. The human physiology is not yet adept at estimating closing speeds or closure rates, whether they are between two aircraft on a head-on pass or an aircraft in a dive.

Appreciation of the fallibility of the human and the criticality of high-speed head-on closures was certainly appreciated by the leader of the *Blue Angels* . In 1995, Cmdr. Donnie Cochran, 41, decided to take his team back into intensive training after lining up above the wrong runway during a high-speed, low-level manoeuvre at Oceana Naval Air Station in Virginia Beach, VA. The Navy's *Blue Angels* suspended their display programme because the team's leader was concerned about his own flying performance and did not want to threaten the safety of the other pilots.

"He made some mental mistakes in the show, mistakes which alarmed him and which caused him to terminate the rest of the performance", said a spokesman for the *Blue Angels* . Each *Blue Angels* manoeuvre involves a series of procedures that have to be performed in precise sequence and with split-second timing. At each show the pilots choose local landmarks as 'marks' from which to stage their manoeuvres. In pilot terminology, Cochran had trouble "hitting his marks".

At Oceana, one of the spectacular manoeuvres in front of a crowd of 150,000 required four aircraft to cross over a single point simultaneously from different directions, using two runways as their 'marks'. Cochran approached the point over the wrong runway but the other pilots saw that he had made that mistake and adjusted to it. The question can be asked: "In that particular manoeuvre, was safety impaired?" Well, it could have been, but wasn't necessarily. However, considering that a total of 22 *Blue Angels* pilots had been killed while training or performing since the unit was formed after WWII, Cochran's appreciation of risk and risk management led him to the only possible conclusion, suspend the display.

The kind of self-evaluation leading to making such a public decision is pretty rare these days when the pressure is to 'do at all cost' and represents its own special brand of courage. It certainly appeared to be a gutsy decision made by a mature leader; leadership of the best sort and in the finest tradition of military service from a display pilot understanding the hazards inherent in high closing speeds. The suspension of their public programme was their second that year and the response of the aviation world was refreshingly surprising. Even considering that the '*Angels'* had already had their programme suspended once during that year: "Good for him! A rational response to the situation. "Better a few missed programmes than an injured or dead pilot or spectator", were typical responses. No doubt some will see this as a sign of individual weakness, but Cmdr. Cochran's decision was the right one and the public statement of the reasons was also correct.

Another classical case of poor judgement of closure rate can be attributed to one of the most spectacular airshow crashes, the Sukhoi SU-30 MKI that crashed at the 1996 Paris Airshow. The twin-seat Sukhoi Su-30MKI attempted to pull out of a descent that included three 'high alpha' downline rolls using vectored thrust. The pilot, short of the proverbial '50 ft extra' tried to recover by using full power and thrust vectoring, but the aircraft jet pipe clipped the ground. In a Reuters report on 13 June 99, the pilot of the Sukhoi-30 MKI apologised, saying that he accepted the blame after attempting an ambitious aerial manoeuvre. "Sorry, I did one too many revolutions in a flat corkscrew and I couldn't pull her out. I didn't have the altitude to get the plane out of the manoeuvre," he said.

And what about the Indian Air Force Mirage 2000 display at the annual Air Force day parade in 1989? After completing an 'upward-Charlie' followed by a short period of inverted flight, the aircraft suddenly pulled down into near vertical downline rolls. The pilot completed three rolls but somewhere along the rolling dive, there was a slight hesitation in the Mirage's attitude before it entered a fourth roll – with catastrophic results.

Why is it that some very experienced display pilots tend to overlook the effects of gravity in the vertical downline? Time delays are extremely critical in the vertical downline, gravity works constantly, and in addition to a rapidly increasing airspeed, gravity only adds

32 feet the first second, but after that, it is 64 feet, 128 feet and 256 feet, etc. So it is easy to see that when certain stick positions require time delays, an extra second or so can make a huge difference between pulling out at a safe height or impacting the ground.

With the exception of the gravitational acceleration force's contribution to the vertical, the energy principles and physics applicable to closure rates, are the same in the vertical plane as they are in the horizontal, head-on case. In the vertical case, the aircraft impacts the ground and, in the horizontal case, it impacts another aircraft. However, the true significance of high closing speeds and slow human reaction times does not lie in making head-on passes, but lies rather in the fact that in spite of high velocities and man's slow reactions, flight can be eminently successful. Although the laws of nature appear to stand rigid and immovable in the paths of aerial conquest, they can, to a certain extent be overcome. Man can find ways and means to compensate for shortcomings in our physiology, however, the safety margins decrease with increase in airspeed and it is to this end that man has established the rules and regulations governing display flying.

DISPLAY ARENA VOLUME

As the number of airshow accidents and incidents has increased and urban growth has expanded over the years to embrace airfields that were originally constructed on the outskirts of cities and towns, so have the number of regulations governing the display 'stage'. Restrictions have been imposed on maximum and minimum heights above ground level, limitations have been imposed on the maximum airspeeds while show volume and noise abatement regulations have been introduced. In fact, all aspects controlling the shape and size of the display arena, have been restricted, placing more and more pressure on the display pilot to fly the aircraft to its limits.

Although there is no standard display arena, considering Farnborough as an example of a restricted display arena, illustrates just how tight the airspace limits have become. Farnborough is not necessary typical, but it is critical because of the conurbations around the airfield and the proximity of the airfields at Blackbush, Odiham and Lasham. The published Temporary Restricted Airspace (TRA) is five nautical miles radius from the airfield centre, increasing to six nautical miles when the formation aerobatic teams are flying. The flying display is of course only allowed to the north of the main runway, which means that the restricted airspace volume is reduced by half, making it particularly physical for pilots flying high speed aircraft trying to keep within the display box - nothing is simple in this world. The maximum height is limited to FL80 within a 3-nautical mile radius from Farnborough, indeed limited volume airspace.

The impact of such restricted volumes of course has a major effect on the high-speed aircraft for which the typical maximum airspeed limit at low-level displays is 600KTAS/M0.92. At that speed, the aircraft would cover approximately ten nautical miles in a minute. It is thus clear that with a five nautical mile radius from show centre, immediately on passing show centre, the pilot has to convert the excess kinetic energy into the vertical or into a tight turn using drag devices such as the airbrakes to decelerate or face exiting the TRA and the wrath of the Flying Control Committee.

One only has to consider the difficulties of the earlier third generation fighters, particularly aircraft developed for the interceptor mission such as the Lightning, Mirage III/F1, F-4 and MiG-21 that had great difficulty in remaining close to the crowd and within the display arena. To stay close to show centre bled a lot of energy in the tight turns and because of the relatively low thrust-to-weight ratios and high wing loadings, display pilots had to extend their routines well past show centre to build-up energy before the run-in for the next manoeuvre. In hot and high conditions, this was particularly embarrassing for a pilot trying to demonstrate the latest 'hotship,' sometimes taking 30 to 45 seconds between passing show centre for each manoeuvre with the obvious risk of course, of losing the interest of the more fickle spectators.

The relatively low specific excess power, (Mirage F1 $T/W_{display} \approx 0.5 - 0.6$) and relatively old wing aerodynamics, forced the pilots to extend by as much as two miles either side of show centre, dependent on density altitude, to coax airspeed from the earlier generation jet designs. With their relatively 'draggy' airframes, sustained high-energy flight routines were only achievable with their engines working overtime in the afterburner range, especially in flying manoeuvres in the vertical.

This is then also the reason why configurations for airshow flying were generally clean or, at worst case, in the air-to-air configuration which of course provided the lighter, less 'draggy' configurations. With the advent of the fourth generation fighters such as the Gripen and Eurofighter and the later models of third generation fighters such as the Sukhoi Su-27 and F-18, it became the 'vogue' to perform 'full-on' demonstrations in the air-to-ground configurations. Aviation specialists quickly picked up on this as being a sophisticated means of 'bragging', of showing just how good a fighter or ground attack aircraft was – after all, a fighter pilot's demeanour is a function of the thrust output of the aircraft they fly. Since then, most modern display aircraft have nearly doubled their T/W ratios making it standard practice to fly displays with a variety of weapons loads and more fuel, all this in an effort, ironically to reduce the T/W ratio to provide a more physiologically useable T/W ratio and making it easier for the display pilot to control the energy and subsequent spacing of the aircraft within the display arena.

For third generation fighters and earlier, the effect of high density altitude was particularly precarious for low specific excess power aircraft, their effective thrust-to-weight ratios being sabotaged by 'hot and high' conditions making energy management a skill. Add to this orographic turbulence caused by heating of the earth's surface and/or surface winds, the pilot's high workload is certainly very high trying to make the 'energy gates' without having to extend on the outbound legs to pick-up energy before turning in for the next manoeuvre. If particular airfields have prohibited overflight areas such as residential areas, weapons storage complexes, high transmitter antennae, old-age homes, hospitals, adjacent airfields, orographic features such as mountains, hills, or valleys, then the pilot's workload increases exponentially trying to comply with the prohibitions. Throw in the odd strong crosswind and the pilot could really have his work cut out fitting the show routine into the display arena with all the hassles imposed by the restrictions.

Obviously low airspeed aircraft such as helicopters, VSTOL aircraft, vintage warbirds and particularly fourth generation fighters and top of the range aerobatic aircraft with their impressively low wing loadings, high thrust-to-weight ratios and scintillating roll rates, are able to maintain the display arena boundaries more easily. With T/W>1, agile, negative stability margin airframes and smart aerodynamics, the problem is no longer one of extending for energy but rather a more painful physical experience as the display pilot's body attempts to absorb the aerodynamic conversion of the aircraft's potential energy into airspeed or tight turns. The bottom line is that the primary task of remaining in view of the spectators to demonstrate the performance and handling qualities of the aircraft within a restricted volume and within a given period at low-level, has its own unique set of challenges and remains a specialist skill.

ENERGY MANAGEMENT

That said, the principles of energy management become particularly critical to the pilot during display flying. In fact, display flying has one thing in common with air combat manoeuvring, and that is, that energy is critical to survival and the safe execution of the display. The principles of energy management in display-flying context are exactly the same for fixed wing as it is for rotary wing and even ultra-light aircraft – "energy is life". Optimising energy management is the basis of the display pilot's skills just as it is the survival tool for the fighter pilot. As in air combat manoeuvring, a high percentage of the display is flown with the engine at maximum continuous power settings or in the case of earlier generation jets, maximum afterburner (excluding the fourth generation fighters, of course) which means that the pilot workload in display flying is essentially a constant exercise in energy management, continuously exchanging potential energy for kinetic energy to generate airspeed or turn rate.

The management of energy during the display is probably the most critical consideration of display dynamics. Display pilots understand that potential and kinetic energy can be exchanged and that the sum of the aircraft energy must be managed to fly the manoeuvres successfully. Specific Excess Power (SEP or P_s in pilot terms), describes the ability of the aircraft to accelerate, climb or turn and from the equation, it is clear that the main factors affecting performance potential, are T/W ratio, Wing Loading, the Drag of the configuration and the Normal Acceleration. It is maybe easier to understand the concept of SEP by realising that Specific Excess Power is essentially the excess thrust (Thrust minus Drag) of the aircraft under the prevailing conditions, divided by the aircraft weight at that instant in time.

$$P_S = V\left[\frac{T}{W} - \frac{qC_{d_0}}{W/S} - n^2 \frac{K}{q}\frac{W}{S}\right]$$

It is thus evident that the major factor providing the aircraft performance potential is the T/W ratio since it is the only parameter that provides a positive contribution to performance and for a given engine thrust, or power output, is maximised at low weights and maximum power. It is for this reason that display pilots strive for maximum T/W ratios and elect to reduce the aircraft weight by reducing fuel weight to a minimum for the required display. On vintage warbirds, weight is typically reduced by eliminating operational equipment such as gunsights, ammunition pans, guns and drop-tanks, etc. In late third and obviously in fourth generation fighters, the T/W ratios are high enough for most display flying requirements and occasions may exist when the fuel load is increased or weapons carried to make the aircraft's energy performance more manageable for the pilot.

Those factors adversely affecting the aircraft's performance potential include the square of the load factor (n); the higher the load factor, the greater the drag effect – the increased apparent weight of the aircraft while pulling g, effectively increases the lift-dependent drag. Of course the higher g induces a higher apparent aircraft weight which in turn increases the wing loading and effectively reduces the manoeuvring potential of the aircraft since the wing's lifting potential is engaged in overcoming the aircraft's apparent weight increase due to g. C_{d_0} of course represents the zero lift drag of the aircraft and the cleaner the configuration of the aircraft, the less the total drag contribution. When $P_s = 0$, the drag of the aircraft exactly equals the thrust so that there is no excess power. This does not necessarily mean that the aircraft isn't climbing, accelerating or turning, but rather that there is no energy available to do anything else – all the available energy is being used for that specific manoeuvre at that instant in time.

As in the case of air-combat-manoeuvring, the display pilot must understand the areas of the aircraft's performance envelope in which maximum performance is attainable and should attempt, for efficiency of effort, to structure the design of the display routine to fit in to an optimised P_s profile for the specific aircraft.

PRESSURE ALTITUDE

Even though display flying is essentially a low altitude activity, pressure altitude and particularly density altitude considerations, are essential to safe display flying. The atmospheric medium, air, is obviously extremely importantto an aircraft's performance, but knowledge of this medium is even more important to the display pilot operating on the 'edge' during low-level display flying. In real world terms, pilots generally tend to associate an increase in altitude with reduced engine performance, but there is more to it than that, especially for the display pilot. Very basically, the effects of increased altitude are characterised by an effective reduction in the partial

where
T/W = Thrust-weight-ratio
q = Dynamic pressure (lbs/ft^2)
W/S = Wing loading (lbs/ft^2)
n = Normal acceleration (g)
K = Constant
C_{d_0} = Zero-lift drag coefficient

where
P = Pressure, Pascals
ρ = Density, kg/m^3
R = Gas constant , J/(kg*deg K) @ 287.05 for dry air
T = Temperature, ºK = ºC + 273.15

pressure of oxygen, air pressure, air density and temperature – all important aircraft performance parameters.

As the air pressure decreases with altitude increase, oxygen continues to account for about 21% of the gasses in the air as it does at sea-level, but there is less oxygen because there is less of all of the air's gasses. For instance, at 12,000 feet, the air's pressure is about 40% lower than at sea level which also means that with each sample of air, the engine is getting about 40% less oxygen than at sea-level. The adverse effects of oxygen partial pressure reduction are the reduction in the combustion capabilities of each sample of air which in turn effects engine performance. This is bad news for the display pilot since any factor reducing engine and therefore aircraft performance, increases the pilot workload and skills level required to display an aircraft.

Considering the basic Gas Law, air density is simply the number of molecules of the ideal gas in a certain volume, in this case a molar volume, which may be mathematically expressed as:

$$P = \rho RT$$

The reduction in air pressure with increase in altitude leads to an effective reduction in air density and while the reduction in temperature effectively increases the air density, it is significantly less than the reduction in pressure. The nett result is that an increase in altitude results in a decrease in air density with all its adverse effects on aircraft performance. Unfortunately, in any discussion of air density, temperature and pressure changes cannot be treated in isolation, they are intimately linked through the Gas Laws, the effect of the one, cannot be considered without considering the effect of the other.

The air's pressure depends on its temperature, its density and how much water vapour is in the air. From basic schoolboy physics, the air's density decreases as the air is heated while on the other hand, pressure has the opposite effect on air; increasing the pressure increases the density by compressing the air. The air's pressure decreases from approximately 1,000 millibars at sea level to 500 millibars at around 18,000 feet and is only about 10 millibars at 100,000 ft. Besides altitude and temperature, weather systems can also change the air's pressure at a given location, however, the weather systems that bring higher or lower air pressure also affect the air's density, but not nearly as much as altitude.

The two important atmospheric parameters that are thus of particular concern to the display pilot are the pressure altitude and the density altitude. The pressure altitude is obviously important primarily for its contribution in providing a pressure altitude reference to the pilot for monitoring height above a given pressure level datum, which in the case of QNH, is the altitude above sea-level. Present day altimeters follow the "Equation of State" and the 1956 U.S. standard assumption. The equation that relates air pressure to altitude:

$$P_a = P_o\,(1 - 6.87535 * 10^{-6} H_c)^{5.2561}$$

where P_a is the air pressure at altitude H_c at a given sea level pressure P_0.

PITOT/STATIC ERRORS

A significant shortcoming in pressure altimeter design of course, is that the pressure altimeter only provides an accurate altitude if the atmospheric lapse rate complies with the standard atmosphere, otherwise, the altitude indicated is in error. The magnitude of the error is a direct function of the temperature deviation from standard.

Besides the accuracy error, there is also 'Hysteresis', an error that is in effect the lag in the altitude indications caused by the elastic properties of the materials used in the barometric aneroids within the altimeter. It occurs when an aircraft initiates a large, rapid altitude change or an abrupt level-off from a rapid climb or descent. It takes a period of time for the aneroids to catch up with the new pressure environment, hence, a lag in indications. This error has been significantly reduced in modern altimeters and is considered negligible at normal rates of descent. However, in the dynamic manoeuvring environment of display flying, there is also reversal error, the phenomenon of reversed readings during abrupt or rapid attitude changes that can occur, but this is usually only of momentary duration. What this means to the display pilot is that the pressure altimeter is basically unusable during low-level aerobatics as an accurate height reference and should only be used as a cross reference to 'Eye-Ball Mk I'.

Another factor affecting the accuracy of the pressure altimeter is Position Error, one of the indirect effects of having the static source affected by pressure changes within the aircraft's flow field. Position Error can result in large pressure altimeter discrepancies in manoeuvres requiring cross control flying techniques such as steady-heading sideslips, knife-edge or 'photo ops' are flown. Dependent on the amount of sideslip and consequently the amount of air being forced into the static system, an indication error occurs. Invariably, the altimeter and airspeed indications may decrease by a few hundred feet and also several knots if rudder is applied against aileron to produce a 'flat turn'. This is due to the ram pressure effect on the static port causing the altimeter static pressure input to experience an apparent higher pressure and consequently indicate a lower altitude. By similar analogy, in the case of the airspeed indicator, an apparent lower pressure differential produces a lower airspeed indication. It must be emphasised that the pressure altimeter and airspeed indication characteristics, position errors and hysteresis are obviously important to the display pilot and must be understood and considered during the design of each of the display manoeuvres.

The hazards of operating an aircraft in close proximity to the ground under visual flight rules, makes the pressure altimeter the primary height reference instrument, for obvious reasons. The simultaneous monitoring of the outside horizon, the airspeed indicator and the pressure altimeter by the display pilot, although essential, increases pilot workload and the last thing that any display pilot needs, is to have to be making pitot/static correction calculations against specific reference points in the manoeuvre. Depending on the vintage of altimeter fitted to the particular aircraft, ambiguity errors in the 3-pointer, 2-pointer displays can also lead to ambiguous interpretation.

"A brief feeling of professional pride was suddenly shattered – something was seriously amiss and the ground abnormally close". (Produced with the kind permission of the Society of Experimental Test Pilots)

Regardless of the selected altimeter subscale setting, extreme care must be exercised with the interpretation of the indications, especially during rapid vertical ascents and descents since misreading the altimeter by 1,000 ft during a low-level display routine could have devastating consequences. The potential areas of the sequence during which altimeter misreads could occur, should be identified and extra care introduced as a 'safety gate' during that particular flight phase.

Besides altimeter indication errors facing the display pilot, the particular option used by a display pilot to set the pressure altimeter prior to flight must be considered. In this case, display pilots performing aerobatics at low-level generally prefer the Zero Altitude Reference by setting the aircraft's altimeter to zero before takeoff which then eliminates the need for the pilot to account for terrain elevation in determining the aircraft's height above ground level. This is effectively setting the altimeter to the QFE datum of the display location, whether it be an airfield or some other location.

There have been reported cases in which inspectors have erroneously informed airshow performers that they must comply with FAR Section 91.121 (altimeter settings) while performing aerobatic routines. FAR Section 91.121 is, however, effectively setting the altimeter to QNE which provides a standard altitude reference for the purpose of maintaining a flight level or cruising altitude and is definitely not appropriate for display flying at low-level.

Since aerobatic routines normally do not involve maintaining a flight level or a cruising altitude, operational safety is not compromised if local aerobatic flight is conducted under VFR using other than the altimeter references specified by FAR Section 91.121. Display pilots mostly favour the QFE setting but some pilots are more comfortable setting QNH. Setting the QFE in effect makes the altimeter read zero at the airfield elevation which then provides a continuous reading of height above ground level and the easiest reference without the need to make continuous subtraction calculations during the various high workload parts of the sequence.

Some pilots of high performance aircraft prefer to set airfield elevation, or QNH, which provides the pilot with the height above mean sea-level. This method is used if the display is being performed at an airfield with significant vertical airspace limits and restrictions; usually airfields close to active civilian hubs, military or international airports – any potential altitude intrusions or 'altitude busts' can be more readily identified by the pilot and averted. In this case, however, the display pilot has to continually calculate the height above ground level by subtracting the airfield elevation from the indicated pressure altitude – an unnecessary addition to pilot workload.

The world famous Hawker's test pilot, Bill Bedford, could speak with authority on the critical aspect of altimeter subscale settings and display flying – he nearly 'wrote himself off' in an unscheduled demonstration in Switzerland, despite being current and in good demonstration practice. The display sequence was designed for the Hawker Hunter in the competition to replace the De Havilland Vampire as the advanced jet trainer of the RAF. The seven minute demonstration sequence started with a straight roll directly after take-off and terminated with a ten to thirteen turn 'smoking spin' from 18,000 ft and starting the recovery at 6,000 ft, provided a 1,000 ft safe margin of height on dive recovery.

Tasked to demonstrate the Hunter in Switzerland and on approaching Emmen Aerodrome near Lucerne, an agreement was reached with the control authorities to carry out a demonstration directly upon arrival. In perfect weather conditions with the basic aerobatic sequence completed, the Hunter smoked itself upwards to 18,000 ft, skewing offset from the centre of the airfield. "Crisp control inputs followed – stick back, full left rudder, full out-spin aileron and she was away rotating like she'd done hundreds of times before. Then stick hard forward to increase the rate of rotation and just sit back monitoring the two single-pointer altimeters as they ticked off the height at some 24,000 ft/min rate of descent. As 6,000 ft came up, full right rudder was applied and the stick moved laterally to port to give a fraction of in-spin aileron. The spin stopped at once with the aircraft dead in line with the centre of Emmen airfield".

"The adrenalin flooded the cockpit as the pilot under pressure became less efficient and realised that he had arrived at "coffin corner". Pull too hard and 'you've had it', don't pull hard enough and 'you've had it', and you've probably had it anyway". He made it with a few a few hundred feet to spare and let the aircraft run on down to tree top level and pull up with a climbing roll, maybe fooling the spectators that it was all part of the show. It was eighteen years before his pride allowed him to admit this near lethal mistake caused by simply omitting to reset the altimeter with the height difference between the airfield and the area over which the spin was carried out.

Then there are of course the pure mechanical failures of pressure altimeters. In the early fifties, a Provost at Farnborough, after a lively display all week, nearly met with disastrous consequences when it barely recovered from a routine spin due to a sticking altimeter. The display pilot apparently celebrated his escape from death with a good party and in the dark, promptly dived into an empty swimming pool and fractured his back!

It can thus be concluded that because of the usual array of altimeter instrument errors, the lag phenomenon during rapid attitude changes, ambiguous interpretation probability and the possibility of mechanical failure, the pressure altimeter cannot and must not be used as the primary height reference during low-level display flying. In fact, the prudent display pilot must rather have a full understanding of the shortcomings in pressure altimeter design and must cater for the inaccuracies and inconsistencies during the manoeuvre and routine planning phases. The pressure altimeter can at best, only be used as an occasional cross-reference for 'Eye-Ball Mk I'.

DENSITY ALTITUDE

Probably the most insidious effect on display flying is that of density altitude – unseen and intangible, it remains a major threat to the display pilot who does not understand its adverse effects. *Density Altitude* is defined as the altitude at which a given density is found in the standard atmosphere and it is best understood by thinking of density altitude as the aircraft's 'performance altitude'. Although density altitude is a convenient yardstick for pilots to compare the performance of aircraft at various altitudes, it is in fact the air density that is the fundamentally important quantity, and density altitude is simply a term to express the air density.

Density altitude begins within the standard atmosphere, a table of air temperature, pressure and density values for each altitude. The Standard Atmosphere is merely a man-made concept, a mechanism by which to map out the atmosphere to enable engineers and scientists to relate atmospheric conditions to standard atmosphere. In fact, rather more like a standardisation tool to enable comparisons to be made, irrespective of prevailing weather or seasonal conditions.

The Standard Atmosphere figures are used to standardise lift and drag calculations of a given aerodynamic shape and even the engine thrust and power output of engines for various altitudes. Density altitude must not to be confused with pressure altitude, indicated altitude, true altitude or absolute altitude, and must not to be used as a height reference, but only as determining criteria to describe the performance capabilities of the aircraft. To take the argument one step further, aircraft performance is a function of density altitude, not pressure altitude, geometric height or any other altitude datum. Even the published performance criteria in the Pilot's Operating Handbook are based on standard atmospheric conditions.

Simply stated, density altitude is the pressure altitude corrected for non-standard temperature. If, for example, the pressure at Cheyenne, Wyoming, (elevation 6,140 feet) is equal to the standard atmospheric pressure for 6,140 feet, but the temperature at that station is 101°F (38.3°C), the equivalent density there is the same as that found at 10,000 feet in the standard atmosphere. The difference between displaying an aircraft at 6,000 feet and 10,000 feet is very significant.

Although there is no specific instrument in the cockpit to measure air density directly, imagine that some kind of device could measure the air's density directly. Imagine that this device indicated that the air's density was 0.001812 slugs per cubic foot. Referring to the Standard Atmosphere Table or computer and against that figure on the chart's look-up tables, the particular density would be associated with 9,000 feet in the Standard Atmosphere. The aircraft would thus effectively be operating at a density altitude of 9,000 feet no matter what the pressure or true altitude it was actually flying. All aircraft performance would then be that which would be achievable on a standard day at a pressure altitude of 9,000 ft with all the consequent adverse effects induced on aircraft performance and handling by higher altitudes.

Most discussions of air density refer primarily to 'dry-air' but in real-world situations, many people who haven't studied physics or chemistry find it hard to believe that humid air is lighter, or less dense, than dry air. Already in 1717, Isaac Newton in his book '*Optics*' stated that humid air is less dense than dry air. Turning to one of the laws of nature, the Italian physicist Avogadro discovered in the early 1800s that a fixed volume of gas, say one cubic metre, at the same temperature and pressure, would always have the same number of molecules, no matter what gas was in the container.

Liquid water is heavier, or denser than air, but the fundamental issue is that the water that makes the air humid, isn't liquid, it's water vapour, which is a gas that is lighter than nitrogen or oxygen. Compared to the differences induced by temperature and air pressure, humidity has only a minor effect on the air's density, nevertheless, humid air is lighter than dry air at the same temperature and pressure. Humidity as such, is thus not generally considered a major factor in density altitude computations because the effect of humidity is related to engine power rather than aerodynamic efficiency. At high ambient temperatures, the atmosphere can retain a high water vapour content, for example, at 96ºF (35.5ºC), the water vapour content of the air can be eight times as great as at 42ºF/(5.5ºC). Fortunately in nature, high density altitudes and high humidity do not often go hand-in-hand. However, if high humidity does exist, it would be wise to add 10% to the required energy levels and anticipate reduced performance.

So under what conditions could the display pilot expect to encounter the worst-case density altitude scenario? The air's density is lowest at a high elevation on a hot day when the atmospheric pressure is low, say at Johannesburg International Airport (elevation 5,511 feet) when a storm is moving in on a hot day. The air's density is highest at low elevations when the pressure is high and the temperature is low, such as on a sunny but extremely cold winter's day in Alaska.

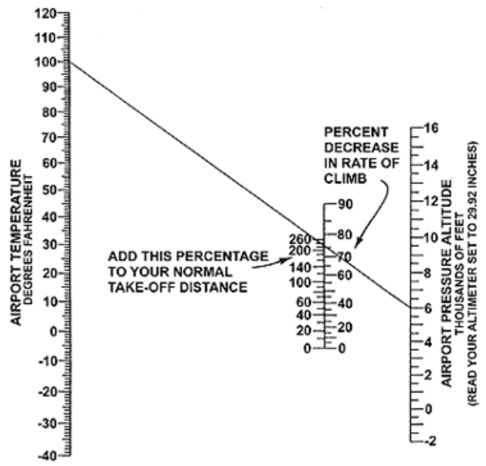
Density altitude effects are not confined to mountain areas, they also apply at elevations near sea-level when temperatures go above standard 59º F (15ºC). If the ambient temperature at sea-level increases to 90ºF (32.2ºC), the equivalent density altitude increases to 1,900 ft, the effects increasing dramatically at the higher elevations. For an airfield elevation of 4,000 ft/45ºF (7ºC), if the ambient temperature increases to 90ºF (32.2ºC), the equivalent density altitude increases to 6,900.

How are high density altitude effects manifested in display flying? Well, for a given set of conditions, lower air density (high density altitude) adversely affects the aircraft's display potential in two ways, performance and handling qualities. More particularly, the lift of an aircraft wing, the aerodynamic drag and the thrust of a propeller blade are all directly proportional to the air density. As such, the aerodynamic lifting force on an aircraft's wings or a helicopter's rotors would decrease, while in terms of engine performance, the actual power produced by the engine would decrease; this includes the thrust generated by a propeller, rotor or jet engine or the horsepower output of an internal combustion engine.

The air, being less dense than normal, will for a given aircraft weight and power setting, reduce all performance parameters such as aircraft acceleration and turning performance which will in turn, adversely effect the size and shape of the airshow routine as well as the selection of manoeuvres. These performance losses more than offset the reduced drag on the aircraft in less dense air. In terms of aircraft handling qualities, a reduction in air density increases the aircraft's apparent momentum due to increased true airspeed while at the same time, aerodynamic damping decreases. Aerodynamic damping is proportional to the relative density factor, in similar proportion to that of TAS to Equivalent Airspeed. The higher the density altitude, therefore, the lower the aerodynamic damping. Although it maybe less significant for display pilots due to the relatively low altitudes at which display flying usually occurs, the effects are nevertheless present.

As an example of just how perverse density altitude effects can be, a quantitative feel for the impact of increased density altitude on take-off distance and rate of climb, a rule of thumb is provided by the Koch Chart for Altitude and Temperature Effects. Example: In terms of take-off distance, the diagonal line shows that 230% must be added for a prevailing Temperature of 100 °F at a pressure altitude of 6,000 feet. Therefore, if the standard temperature sea level take-off distance in order to climb to 50 feet normally requires 1,000 feet of runway under standard conditions, it would increase to 3,300 feet under the conditions shown – a significant increase.

In terms of the rate of climb, a decrease of 76% would result. If the normal sea-level rate of climb was 500 feet per minute, it would reduce to 120 feet per minute – once again a significant performance degradation that cannot be ignored. This chart indicates typical representative values for a generic aircraft type but for exact values, the specific aircraft's flight manual must be consulted. It is pertinent to note that the chart is conservative for aircraft with supercharged engines.



The Koch Chart for Altitude and Temperature Effects.

At airfields of higher elevations such as those in the Western United States and in the northern parts of South Africa, high temperatures sometimes have such an effect on density altitude that safe display flying in low powered and small aircraft is jeopardised. In such conditions, display flying between mid-morning and mid-afternoon can become hazardous, especially if the high temperatures are accompanied by strong orographic turbulence.

But even at lower elevations, aircraft performance can become marginal and it may be necessary to reduce aircraft gross weight for safe displays. It is therefore advisable that when performance is in question due to excessively high density altitude, to schedule displays during the cooler hours of the day, early morning or late afternoon. Early morning and late evening are sometimes more ideal and this is one of the reasons that the Shuttleworth's Collection of flying WWI vintage aircraft operating out of Old Warden (UK), normally start their shows in the late afternoon when there is supposedly 'more lift in the air'.

All too often, a pilot who is displaying in high density altitude conditions for the first time in an aircraft with a normally aspirated engine becomes painfully aware of the retarded effect on the aircraft's performance capabilities. At power settings of less than 75%, or at density altitudes above 5,000 feet, it is essential that normally aspirated engines be leaned for maximum power for all manoeuvres unless equipped with an automatic altitude mixture control, otherwise the excessively rich mixture further reduces the engine's power output and the overall performance of the aircraft.

Turbochargers or superchargers effectively increase the density of the air going into an engine thereby extending the power output of the engine and allowing the aircraft to operate at higher, less dense altitudes than they would otherwise. Supercharging thus enables the engine to maintain sea-level values up to the critical height of the supercharger. In relative terms then, and up to the critical height of the engine, superchargers provide increased performance at the higher density altitude airshows helping to offset the adverse effects of density altitude. Within the altitude range of the turbocharger, engines need thus not be leaned for manoeuvring in high density altitude conditions because they are capable of producing manifold pressure equal to or higher than sea level pressure.

Again trying to provide a 'gut feel' to describe the extent of the adverse effects of density altitude, a normally aspirated engine will lose approximately 3% of its power per thousand feet of density altitude increase. For a generic general aviation type aircraft at an airport with an elevation of 5,000 feet and a temperature of 100°F (32.2ºC), the aircraft would perform as it would at 9,000 feet on a standard day. Assuming a standard lapse rate, if the service ceiling was 15,000 feet for the particular aircraft, the aircraft would typically 'max out' at 11,000 feet on a hot day with maximum all-up-weight.

High density altitude is so insidious, it can't be seen, but it is there. If ignored, the display pilot may meet it at the top of a vertical manoeuvre where the aircraft just seems to 'run out of steam' trying to reach the apex. One of the secrets of surviving as a display pilot is that if the pilot recognises that the aircraft energy level is outside the 'energy gate', it is imperative not to force the recovery but to rather fly the pre-planned exit manoeuvre.

Thinking back to the Trislander crash at Lanseria in 1977. A Company test pilot demonstrated the Trislander; the airfield elevation near Johannesburg is in excess of 5,000 ft and with a prevailing temperature on the day of the accident at 30ºC, the density altitude was approximately 8,500 ft. Amongst other manoeuvres, a loop was included in the display sequence. During the practice sessions, it was evident to the pilot that the density altitude was critical to aircraft performance and achieving the ‘energy gate’ conditions for the safe accomplishment of the manoeuvre. As it turned out, the sequence progressively lost energy with the result that at the apex of the loop, the aircraft was too low which resulted in insufficient height to safely effect the recovery pull-out. It was estimated by reliable witnesses that the proverbial ‘another 50 ft’ might have been sufficient to avoid impact with the ground. Conversely, if the temperature had been 5ºC cooler, the aircraft might just have made the 50 ft shortfall, in theory, of course.

Display pilots need to understand the impact of the performance and handling qualities deviations resulting from changes in density altitude. Display pilots must learn to adjust their demands from the aircraft caused by changes to the values of lift, power and thrust taking into account the differences between the standard atmosphere and the real atmosphere at the display location. In other words, respect density altitude. Especially sensitive to density altitude effects are the Harrier and most helicopters, particularly in the hover. As the outside air temperature increases, so the hover performance of the aircraft becomes more critical and the Harrier typically has only 1.5 minutes of water to cool the engine during hovering demonstrations and displays have to modified according to outside air temperature.

Because of the inescapable influence density altitude has on aircraft and engine performance, it is important for every pilot to understand its effects. Hot, high, and humid weather conditions can change a routine display into an accident in less time than it takes to tell about it. The pilot must understand the exact impact on the airshow routine and the necessary handling techniques must be modified to compensate for the reduced energy levels.

From the pilot’s perspective therefore, an increase in density altitude is manifested in increased takeoff and landing distances, reduced rates of climb, increased true airspeed for the same IAS, increased turn radius for a given IAS while the maximum level airspeed obtainable is also reduced. Best rate of climb airspeed decreases as altitude increases, while best angle of climb airspeed increases slightly. In the final analysis, the effect of increased density altitude is to effectively reduce the potential power of the aircraft and the ability to manoeuvre dynamically. Display pilots must therefore refer to the specific aircraft’s handbook or flight test results to be sure that they are flying the correct airspeeds to get the optimum or maximum performance from the aircraft.

IAS/TAS RELATIONSHIP

Another insidious but significant effect of temperature and density is on the indicated airspeed/true airspeed (IAS/TAS) relationship, surely the most neglected parameter of aircraft handling and performance by display pilots. This is a fundamental relationship which affects every single second and every aspect of the display. Why is it important? Well, because TAS is the main dynamic factor in linear momentum, moment of inertia, and kinetic energy, which in display flying terms, constitutes the essential elements to be considered in energy management. In addition, TAS is also a primary factor in the aerodynamic forces and damping moments that contribute to aircraft stability and thus aircraft handling qualities. The fact of the matter is that the primary factor affecting the IAS/TAS relationship is of course, the density, and hence, temperature and altitude.

Reference to the equation for True Airspeed is required for better understanding of the effects of air density on TAS:

$$V = \frac{V_e}{\sqrt{\sigma}}$$

In terms of density altitude then, it bears mentioning that TAS and IAS are equal only when the density altitude is zero with the trend being that TAS is always greater than IAS as density altitude increases. Thus, the rule of thumb is that for a given pressure altitude, the higher the temperature, the lower the density of the air and therefore, the lower the relative density which for a given Equivalent Airspeed, implies a higher TAS. For a given equivalent airspeed V_e, therefore, TAS is inversely proportional to the relative density, which in turn is inversely proportional to the temperature.

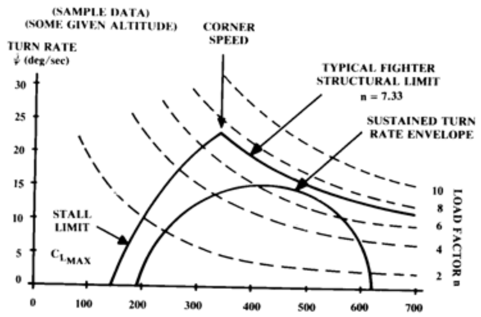
TURN PERFORMANCE

Turning is obviously an essential element of any airshow routine and the optimisation of the turn and turn-around manoeuvres, can often mean the difference between an aesthetically appealing display routine or a 'wide, wet' show. In terms of spectator appeal, turn rate and turn radius are the cornerstones to keeping the show routine tight. Within the regime of turn performance, the display pilot should aim to optimise both instantaneous and sustained turn rate performance within the show routine, demonstrating agility, manoeuvrability and controllability. More particularly, abrupt pull-up/pull-down manoeuvres, the "Double Dip" (abrupt pull/push/pull/pirouette), and the Pirouette, are all optimally performed at the airspeed for maximum instantaneous turn rate.

Every display pilot hoping to achieve maximum turn performance within a highly dynamic sequence, must know and understand the optimum turning conditions for the specific conditions of aircraft weight, altitude and airspeed. Understanding the concept of corner speed is therefore essential to the display pilot, just as it is for the fighter pilot. An advantage of operating at 'corner speed' is that pilot workload is reduced somewhat and the pilot should theoretically, not exceed the maximum g-limits and with the relatively higher energy available, the possibility of departure is reduced.

where
V = TAS (ft/sec)
V_e = Equivalent Airspeed (ft/sec)
$\sqrt{\sigma} = \frac{\sqrt{\rho}}{\sqrt{\rho_o}}$, the relative density factor which is a function of T and P

Before considering the theory, it must be said that it is all very well addressing display flying and energy management principles in theory, but in practice, it is more difficult to implement due to the dynamic nature of manoeuvring; the continuously changing energy levels making it difficult to optimise performance exactly throughout every second of the display. That said, it not only makes it challenging to attempt to operate on the edge of the flight envelope in terms of handling qualities, but also in the case of aircraft performance. In today's competitive and cut-throat business of Product Demonstration and Competition Flying, maximizing the aircraft's performance potential may mean the difference between winning or losing the competition or making or failing to make the sale. As such it is essential to have a good understanding of the optimum airspeeds and angles of attack for each particular manoeuvre.



Graphic depiction of turn performance for a generic fighter type aircraft. (Reprinted from Aircraft Design: A Conceptual Approach, copyright 1999 D. Raymer, All Rights Reserved, used with author's permission.)

All pilots know that in level turning flight, the lift is tilted so that the horizontal component of the lift generates the centripetal force required to turn. The total lift on the wing is thus *n* times the aircraft weight *W,* and without going through the math, the horizontal component of lift is *W* times the square root of $(n^2 - 1)$. In the geometry of the level turn, instantaneous turn rate is then simply equal to the radial acceleration divided by the velocity and can be described mathematically by:

$$\psi_{instantaneous} = \frac{g\sqrt{n^2 - 1}}{V} \quad (°/sec)$$

It is also pertinent to note that in the case of the instantaneous turn rate parameter, it is independent of aircraft weight and is limited only by the usable maximum lift up to the

where
n = Load factor (g)
g = Gravitational constant, 32.2. ft/sec^2
V = True airspeed (ft/sec)

speed at which the maximum lift equals the load-carrying capability of the wing. The airspeed at which the maximum lift available exactly equals the allowable load factor, is called the 'corner speed' and provides the maximum instantaneous turn rate. It could be more aptly described as the airspeed at which the stall limit (lift boundary) and structural limit airspeeds, intersect. The only practical limit for the display pilot however, is the quality of the lift at corner speed where maximum g may not necessarily be available due to the amplitude and frequency of the buffet which ultimately effects controllability. The use by the pilot of lift generating devices such as slats and combat flaps would in such a case, certainly be beneficial for keeping the show tight and reducing the intensity of the buffet, provided of course that the devices are cleared for operation at those particular airspeeds.

In most high performance combat jets with conventional flight control systems, the 'corner speed' is usually between 300 and 350 kts. Operating at corner speed optimises the energy utilisation thereby allowing the display pilot to convert all available energy to turn or agility demonstrations without exceeding the normal acceleration limitations. Thus, for optimising turning manoeuvres within the display routine, display pilots, where possible, should attempt to operate close to corner speed to keep the show routine tight. This requires the display pilot to find the best balance between normal acceleration and the true airspeed.

The next issue for consideration is that of the sustained turn. In the case of the 'sustained turn' physics, the aircraft maintains a constant airspeed and altitude, the thrust equals drag and the lift equals load factor times weight. Thus the maximum load factor for sustained turn can be obtained by maximising the product of the thrust-to-weight and the lift-to-drag ratios.

$$n_{sustained} = f\ \{(T/W)(L/D)\}$$

What this means to the display pilot is that sustained load factor can be optimised by flying at the lift coefficient for maximum lift/drag (L/D), maximum thrust and minimum weight (T/W).

$$n_{sustained} = \sqrt{\frac{q}{K(W/S)}\left(\frac{T}{W} - \frac{qC_{D_0}}{W/S}\right)}\ (^{\circ}/\text{sec})$$

From studying the sustained turn equation it is evident that maximised performance is primarily a function of the excess thrust, namely, thrust minus drag. The parameter to be maximised for optimum sustained turn performance therefore is T/W ratio and that to be minimised, the zero-lift drag due to aircraft configuration – the cleaner the aircraft's configuration, the less the Cd_0.

where
n = Load factor (g)
q = Dynamic pressure (lbs/ft^2)
K = Constant
T/W = Thrust to weight ratio
Cd_0 = Zero-lift Drag Coefficient
W/S = Wing loading (lbs/ft^2)

Vectored thrust of course, offers the display pilot an added dimension to the display routine design. The significantly improved turn performance capability for VSTOL aircraft such as the Harrier and the Joint Strike Fighter, will continue to encourage innovative manoeuvring. The dynamics of VSTOL turning manoeuvres are a function of the angle and the amount of vectored thrust being applied while the direction which the thrust must be vectored by the pilot, depends upon whether instantaneous or sustained turn-rate is to be maximised. The mechanics of this situation very basically then is that in a level turn with vectored thrust, the forces can be simply expressed as:

where
n = Load factor (g)
VTh = Vectored Thrust component
W = Aircraft weight (lbs)
L = Lift (lbs)

nW = L + VTh

This essentially means that thrust is being utilised to complement the lift in supporting the weight of the aircraft. Obviously for maximum instantaneous turn-rate, the thrust vector should be perpendicular to the flight direction but since none of the thrust would then be propelling the aircraft forward, the aircraft would decelerate dramatically. This is a tactic used by operational VSTOL jet fighter pilots to force the overshoot in turning combat by inducing rapid decelerations by vectoring in forward flight. For airshow spectators that understand the dynamics of manoeuvring an aircraft in three dimensions, this is always rather impressive to watch and even the less knowledgeable spectator has been heard to remark on such dynamic decelerations, especially transitioning from high speed flight to the hover in 180º of turn.

where

V^2 = True Airspeed (ft/sec)
g = Gravitational constant g 32.2 ft/sec^2
θ = Bank angle (degrees)

Knowledgeable critics such as test pilots and professional display pilots will most probably notice aircraft agility, turn and pitch rates during displays while the avid spectator will be more inclined to appreciate turn performance capability in terms of tight turn radii. Whereas turn rate primarily addressed the time to turn through a given number of degrees, the other important display consideration in the horizontal plane is the radius of turn which is proportional to the square of true airspeed as indicated in the equation:

$$R = \frac{V^2}{g \tan\theta} \text{ (ft)}$$

Because of the fixed physical relationship between bank angle and normal acceleration in a level turn, there are only two variables that affect the turn radius, TAS and bank angle. The contribution from TAS on turn radius is, however, significant due to the square relationship of airspeed on turn radius. Any increase in airspeed due to poor speed control by the pilot or by temperature effect on the IAS/TAS relationship, affects the turn radius noticeably. Doing the math, if TAS is increased by only 10%, the turn radius will typically increase by 20%.

In the display arena this may result in a wider than expected positioning turn resulting in overshooting the desired ground track or an excessively wide airshow. At high density altitudes, the display pilots will have to fly slightly wider patterns to account for the wider turn radii. The display pilot must recognise that in certain high density altitude conditions, the ‘horse may be flogged out’ and is no longer capable of producing the required energy levels. The danger here is that the display pilot’s patience could be tested by performance reducing high density altitudes, increased turn radii and slower accelerations making the show wider than anticipated, even with maximum engine thrust. The worst thing the display pilot could do in these circumstances is to attempt to ‘press’ the routine and try to ‘squeeze’ the desired excessive performance from the aircraft. The prudent display pilot will understand the phenomenon and patiently wait for the energy to increase by flying slightly wider. Failure to do so could result in a rapid decrease in total energy with very little potential for manoeuvring and possibly converging to catastrophe.

where
V = TAS (ft/sec)
g = 32.2 ft/sec^2
θ = Bank angle (degrees)

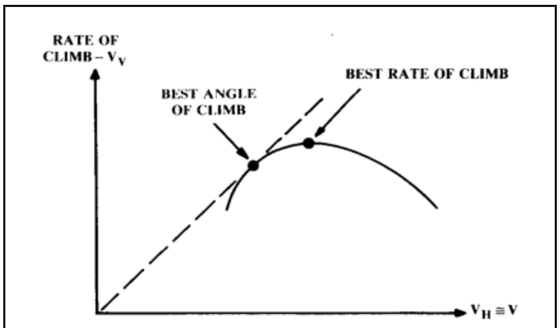
Although not directly a significant factor in display flying, it is instructive to consider the equation for time (t) to turn one degree then is

$$t = \frac{\pi V}{180 g \tan\phi} \quad \text{(secs)}$$

This equation illustrates that the amount of time to turn one degree which is thus directly proportional to the velocity and inversely proportional to the angle of bank. What this implies for the display pilot is that it takes longer to turn at a high speed, but less time to turn at a large angle of bank. The interesting point is that rate of turn is directly proportional to V while radius of turn is proportional to V^2. Simplistically stated, this means that if the aircraft flies twice as fast, the radius of turn will be four times as great, but the time to turn will only double.

CLIMB PERFORMANCE

To the spectator, one of the most impressive manoeuvres from which to commence the sequence is the take-off rotation, whether it be a high performance jet, large transport or even a general aviation aerobatic category aircraft. It somehow has a ‘wow’ effect to see the machine rapidly convert the take-off run into the vertical and climb away either at maximum rate of climb or maximum angle of climb. The ‘best rate of climb’ obviously provides the maximum vertical velocity, while the ‘best angle of climb’ provides a slightly lower vertical velocity but at a reduced horizontal speed, maximize the effective climb angle - the aircraft gains more altitude for a given horizontal distance. Either manoeuvre is equally impressive, either to fly as the display pilot or to watch as a spectator.



Graphic depiction of climb performance. *(Reprinted from Aircraf Design: A Conceptual Approach, copyright 1999 D. Raymer, All Rights Reserved, Used with author's permission.)*

The airspeeds for both manoeuvres are determined during flight test and are readily obtainable from the particular aircraft’s performance manual. Most propeller aircraft have the best angle of climb speed at about 85% - 90% of the best rate of climb speed. Climb performance, whether best angle or best rate, is obviously a function of excess power, or more correctly, power available versus power required divided by aircraft weight. The best rate of climb is thus that airspeed at which the vertical velocity is a maximum at the prevailing conditions of thrust, altitude, temperature, weight and may be expressed by:

$$V_v = V\left(\frac{T - D}{W}\right) \quad \text{jet case}$$

or

$$V_v = \frac{550 bhp \eta_p}{W} - \frac{DV}{W} \quad \text{propeller case}$$

which, although not strictly speaking very accurate, is applicable if the climb angle γ is small enough that lift is approximately equal to weight. What is particularly important for the display pilot to understand is that the published best rate of climb or maximum angle of climb airspeed, varies with altitude.

In terms of handling considerations, and by the very nature of the dynamics of the steep takeoff rotation, the manoeuvre requires some fine piloting skills. It may look pretty simple, but to fly it safely, it must be flown at maximum aerodynamic efficiency so as to retain energy. It is not just a case of pulling back at a certain speed and pushing over at the next aim speed.

The handling techniques to ensure safety of flight in the manoeuvre planning phase, must consider the rotation phase and the level off from the performance climb demonstration. It is extremely prudent to ensure that sufficient energy is available for the rotation or else the effect of a too early rotation could be to pull the aircraft into the backside of the drag curve, preventing the aircraft from being able to climb away at a constant airspeed. By the same token, sufficient airspeed must be available to enable the aerodynamic power to push-over for recovery from the climb or alternatively, banking into a wingover to assist in getting the nose down if required. The hazards here are that the aircraft is operating at the low speed end of the flight envelope and therefore on the backside of the drag curve which is particularly critical in the case of swept wing and delta wing aircraft that inherently have high lift induced drag.

Equally important is the flap position and the aircraft centre of gravity. It is not impossible on certain aircraft to find that the downwash created at extreme angles of attack with flap down, reduces the elevator authority, significantly. A display pilot having rotated at a very high angle of attack could find that the extreme climb away angle may look spectacular to the spectators, but if there is insufficient pitch authority to command the nose-down attitude to level off, the final resulting crash would look even more spectacular. The impressive display of the USAF C-17 short take-off rotation is performed at V_{rot} + 10 kts to increase pitch control while the climb is conducted at minimum climb-out airspeed V_{mco} +10 kts which is about 20% higher than aircraft stall speed at that weight and provides the display pilot with a safety ‘energy buffer’. It is after all said and done, extremely important that the energy is managed with care since there is usually insufficient altitude available to convert height into airspeed should this manoeuvre be ‘cocked-up’ by the display pilot.

GROSS WEIGHT AND CENTRE OF GRAVITY

Ask display pilots what the effect of increased weight is on the display routine and they will all be able to tell you that performance degrades as a direct function of aircraft weight increase. So every display pilot knows the adverse effect of increased mass on aircraft performance, but does the pilot know by how much? And what about the often forgotten aspect of weight on centre of gravity?

where
V_v = Vertical velocity (ft/sec)
V = True Airspeed (ft/sec)
T = Thrust (lbs)
D = Drag (lbs)
W = Weight (lbs)
Bhp = Brake Horsepower

An SAAF test and display pilot, Lt Col Des Barker, flying a Mirage F1 at a Port Elizabeth airshow in 1992, can bear witness to the adverse effects of increased mass on a display routine and the disbelief induced by realising that a ‘guesstimate’ of how much compensation must be applied is just not good enough. The display pilot must know that low-level manoeuvring does not provide the luxury of a second chance to try it again, it has to be right, first time.

The sequence commenced from take-off with a 20º nose-up pitch rotation leading directly into a 270º-aileron roll in the take-off configuration, exiting directly into an accelerating 360º steep turn while cleaning up the configuration. The display routine had been practiced in the take-off configuration of undercarriage down and combat flap with a half internal fuel weight of approximately 2,000 litres. The high induced drag during this flight phase demanded maximum performance from the aircraft and could be safely flown with half internal fuel at most of the density altitudes that could be encountered at sea-level – this provided a safety buffer.

Due to unforeseen logistical problems with tyre availability on the show day, only one more landing was available before one of the main-wheel bogie tyres had to be changed. It was decided that the display would have to flown at a full internal fuel weight of 4,300 litres and the aircraft then recovered directly back to home base, 250 nautical miles distant on completion of the display - without landing back at Port Elizabeth. The pilot realised that the initial part of the display would need to be flown a lot looser until the fuel weight had decreased. The sequence had not been practiced at maximum weight for the clean configuration and needless to say, in an effort to keep the show as tight as possible under the circumstances, the 'thumb-suck guesstimate' amount to loosen the show was inadequate – the result being that the energy bleed-off in the aileron roll at the higher angle of attack caused by the mass increase, was far in excess of what had previously been encountered.

The knock-on effect was that there was insufficient energy available to fly the steep turn tightly, in fact, the aircraft had to be unloaded from only 200 ft agl to 100 ft agl and at such a low altitude, there was insufficient height available to unload the aircraft further to accelerate. The high induced drag generated by operating so far on the backside of the drag curve at the increased mass and the low specific excess power, instead, left the aircraft, all 12 tons, hugging the rooftops of surrounding homes at full afterburner. The aircraft was captured in a 'low energy box' with no specific excess power available to accelerate out of the box and with no height to unload and increase energy. The angle of attack warning horn camouflaged the incipient stages of wing-rock for which the swept wing Mirage F1 was well known at 5º above the Manufacturer's limit of 17º incidence – there but by the grace of God. Any thoughts on ejection in the face of possibly losing control of the aircraft? No, ejection was not even considered as an option, not with the peripheral vision flooded by the residential area's house's roofs in the early morning sunlight. It is highly unlikely that any pilot would, under similar conditions, have had the courage to eject, not with the possible horrendous consequences. This is most probably the same emotion experienced by the pilot's of the Ukrainian Air Force Su-27 that crashed into the spectators in July 2002.

The effect of weight impacts on the performance of the aircraft on the one hand, and on the handling and flying qualities, on the other. Increased mass basically increases the lift-induced drag while aircraft handling is also adversely affected due to increased momentum and of course, the effect on the changes to the centre of gravity position. The effect of fuel burn-off can move the CG significantly, and is particularly relevant in high-speed jets with high fuel burn rates. Besides fuel burn, the carriage of underwing stores, fuel drop tanks or the dropping of any form of ordnance or ballast can rapidly change the CG position and the resulting handling characteristics of the aircraft.

One particularly precarious situation that must be considered for aircraft fitted with underwing/fuselage fitted fuel tanks, is the 'sloshing' effect of the fuel in the tanks. Most fuel drop-tanks are fitted with 'surge plates' or are compartmentalised to prevent the fuel from surging forward or backwards during dynamic manoeuvres. A rapidly changing CG during a manoeuvre could quite easily induce pilot induced oscillations (PIO) with subsequent catastrophic effects if the pilot's response becomes out of phase with the aircraft's motion. A forward CG reduces the aircraft's agility and manifested in the cockpit by greater stick force/g while an aft CG increases the agility of the aircraft but in the process, reduces the stabilizing contributions from the empennage. It is incumbent on the display pilot to know exactly what the weight of the aircraft is, the location of the CG and not only the change of the CG during the display but also the effect on handling qualities.

In terms of performance, all aspects are affected and as such, the display pilot must know the exact effect of weight increase on aircraft performance, it is not an 'ad hoc' or 'thumb-suck' adjustment that can be made on the spur of the moment. It is therefore advisable that the display sequence be planned for a given mass within a known scatter band of weight and CG locations.

PILOT INDUCED OSCILLATIONS

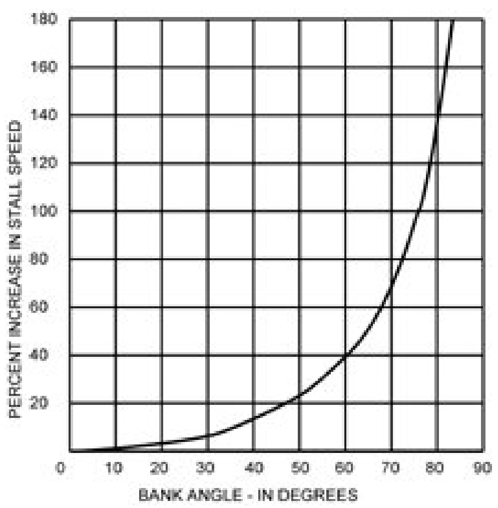
A problem that has handicapped aircraft design and aircraft handling characteristics since the inception of aviation, is that of the Pilot Induced Oscillation (PIO). The pilot may purposely induce various motions to the aircraft by the action of the controls. In addition, certain undesirable motions may occur due to inadvertent actions on the controls by the pilot or even by atmospheric disturbances. In particular, the display environment is a particularly susceptible regime – airspeeds, attitudes and angles changing at very high rates during the various manoeuvres. The elements of atmospheric turbulence and sudden CG position changes increase the possible permutations for PIO's. The PIO has its origins in the short period longitudinal stability of the aircraft where pilot-control system response lag can produce an unstable oscillation. The coupling possible in the pilot-control versus system-aircraft combination is most certainly capable of producing damaging flight loads and loss of control of the aircraft.

To better understand the concept, it is essentially a case of the human response time getting out of phase with the motions and response rate of the aircraft. On the one hand the pilot has certain response/reaction times which when out of phase with the response frequency of the aircraft, can lead to the oscillations. When the normal human response lag and control system lag are coupled with the aircraft motion, inadvertent control reactions by the pilot my result in a negative damping to the oscillatory motion and dynamic instability will exist. Since the short period motion is of relatively high frequency, the amplitude of the pitching oscillation can reach dangerous proportions in an amazingly quick time; measured in a few seconds before catastrophic structural failure could occur. Any attempt to forcibly damp the oscillation simply continues to excite and amplify the oscillation. Freeing the controls removes the unstable pilot input and allows the inherent stability of the aircraft to damp the motion.

The PIO is most likely if the pilot is unfamiliar with the 'feel' of the aircraft and could be the result of 'over controlling' by the pilot or excessive response lag. High speed, by its nature, is likely to provide highly sensitive response and periods of oscillation which coincide with the pilot-control system response lag. Particularly dangerous of course is the high-speed regime in which the amplitude of the oscillation may provide sufficient energy for in-flight structural failure. If a PIO is encountered, the pilot must rely on the inherent static and dynamic stability of the aircraft design and immediately release the controls since unstable excitation, if continued, can lead to structural failure. Obviously, it is imperative that the aircraft must be operated within its cleared flight envelope.

LOAD FACTOR

One of the aspects that separates display flying and aerobatics from the more mundane general aviation flights, is the dynamic manoeuvring environment of the aircraft in which load factors range between maximum positive and maximum negative g for the particular aircraft on display. Since load factor represents the ratio of lift being produced relative to the weight of the aircraft at that particular instant in time (n_z= L/W), it is of critical importance to the display pilot. Besides the tiring physiological and physical effects on the human body, high g adversely affects the structural loading and long-term fatigue life of the aircraft. The prognosis on airframe fatigue is not only short term buckling and stretching, but also long term structural failure. Physiologically the effect on the pilot of high g is usually manifested by 'blackouts', red-outs, or G-LOC with the crucial aerodynamics effects on the aircraft of sustained load factor being the stall and departure.



Effect of change of bank angle on stall speed.

The prudent consideration for the display pilot and a fact that must be imprinted on the mind of the display pilot, is the effect of load factor on stalling airspeed. The slope of the curve for the increase in stall airspeed with increase in bank angle, increases rapidly above 30° bank angle and load factor increases approaching infinity as the angle of bank approaches 90°. The 90° banked, constant altitude turn is not mathematically possible although display pilots often elect to fly the 'knife-edge' to demonstrate a feat which theoretically cannot be flown. In this case however, at 90º-bank angle, with the wing lift vector tilted at right angles to the flight path, the pilot is forced to use the

rudder as the elevator, to maintain the nose position on the horizon. An aircraft can be banked to 90° and even sustained in straight flight for a short period of time, but a continued coordinated turn is impossible at this bank angle without losing altitude. Although the load factor can be mathematically calculated for nearly every bank angle, it has very little direct importance on the display manoeuvres but the basic understanding of the effects of an increased bank remains fundamental to the safe display of the aircraft.
The basic tenet that display pilots must cater for is the effect of weight increase on stall speed due to the actual weight increase or the apparent weight increase due to g-loading. A stall occurs when the angle of attack is increased to a value at which the airflow over the airfoil breaks away, producing an abrupt loss of lift which can no longer support the aircraft weight. In unaccelerated flight, a stall will occur at a certain angle of attack, approximately 16º for most conventional aerofoils and is independent of airspeed under most conditions. This principle applies at all angles of attack, including the stall, so the upshot of this is that if the wing loading is increased, the airspeed at which the critical angle of attack is reached, is greater. That is, the heavier the aircraft, the faster the aircraft stall speed or conversely, the greater the load factor, the greater the stalling speed – even though the angle of attack remains the same. Most aircraft are placarded with a ‘stall speed’ at maximum all-up weight in straight and level flight.
There are some conditions where the aircraft’s wing loading effectively changes in flight. The most obvious of these is in pull-ups or turns. In a 45º turn, for example, the effective weight of the aircraft is increased by a factor of 1.414, and this is the reason extra airspeed is required in turns - the stall speed in a level turn is greater than in straight flight. An aircraft can also enter an ‘accelerated stall’ by doing a very fast pull-up i.e. raising the nose very quickly after a dive, even at relatively high airspeeds. In this case, even though the aircraft has excessive airspeed, the pilot has rotated the wing very quickly to, or beyond the critical angle of attack, and it will enter a high-speed stall.
In the absence of an angle of attack indicator, the approaching stall can be derived from the aircraft’s airspeed. Manipulating the lift formula provides the relationship between the airspeed and the angle of attack.

$$L = \frac{1}{2}\rho V_S^2 S C_{L\max} = W$$

or

$$V_s = \sqrt{\frac{2W}{\rho S C_{L\max}}}$$

$$V_s \approx f\{\frac{W}{C_L}\}$$

where
- L = Lift (lbs)
- D = Drag (lbs)
- ρ = Air density (slugs/ft^3)
- V = Velocity (ft/sec)
- S = Wing area (ft^2)
- C_L = Lift coefficient
- C_D = Drag coefficient

It should be noted that the wing area (S) and the air density (ρ) for a given altitude, is constant while both C_L and the velocity (V) are variables. The velocity is a major contributor to lift and drag and both are proportional to the square of the velocity. From the lift and drag formulae, it follows that the velocity and the angle of attack (represented by C_L) is inversely proportional. The speed (V), therefore, is a function of the angle of attack (C_L). It also demonstrates a direct relationship between the airspeed V, the weight of the aircraft W and the lift coefficient C_L. Increasing the load factor to a value where the generated lift can no longer support its weight, will result in a stall. The following formula demonstrates the relationship of the load factor and the stalling speed.

$$Vs_2 = Vs_1\sqrt{n}$$

Increased load factors are a characteristic of all manoeuvres and become significant both to flight performance and to the aircraft's structure as the bank angle increases beyond approximately 30°. The abrupt pul l-up at a high airspeed can easily produce critical loads on structures and may produce recurrent or secondary stalls by increasing the load factor to a point exceeding the stall angle of attack during the pull-up. All of the foregoing basic theory is taught to all pilots from day one – yet airshow and display accident statistics are fraught with cases of those pilots that have chosen to ignore the physics. The first rule of flight is to overcome the weight of the aircraft, why then ignore this basic impediment of flight by entering a regime in which lift is no longer at least equal to weight?

where
Vs_2 = Accelerated stall speed
Vs_1 = Unaccelerated stall speed
n = Load Factor

STRUCTURAL LOADS

Surely one of the most important elements that must be considered by the display pilot is the inherent structural load on an aircraft and its systems during display flying. The analysis of airshow accidents in Chapter 3 identified six (5%) structural failures which was 30% of the contribution to mechanical failures. While the pilot's rather elastic and flexible body is capable of handling most of the stresses and strains imposed by the rigours of display flying, the engine and airframe materials may not be capable of absorbing such sustained excessive loading. When one thinks of aircraft loads, the airloads due to high g manoeuvres immediately come to mind and yet while important, manoeuvring loads are only a part of the total loads that must be withstood by the aircraft structures. The lifting surfaces are obviously always critical under the high g manoeuvre conditions and irrespective of the type of aircraft, fatigue loads are induced on the aircraft structure through airloads, inertia loads and the engine loads which may be further subdivided as indicated in Table 1.

Airloads	Inertia Loads	Powerplant
Manoeuvre	Acceleration	Thrust
Gusts	Rotation	Torque
Control Deflections	Vibration	Gyroscopic
Buffet	Flutter	Vibration
		Duct Pressure

Table 1. Further sub-divisions of aircraft loads.

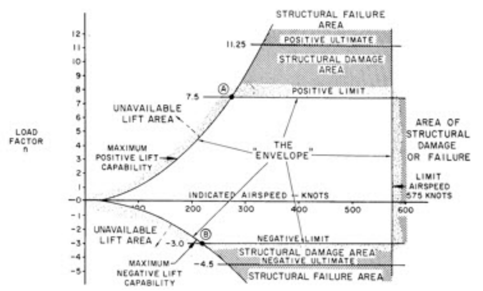
By definition, the static strength requirements consider the effect of simple static loads with none of the ramifications of repetitive cyclic variation of loads. An important reference point in the static strength requirement is the 'limit load' condition. For each aircraft, there is some maximum load which would be anticipated from the design mission, whether it be aerobatics, light utility, ground attack, or transport, etc. The largest stress loading the aircraft is actually expected to encounter in its role, is the 'limit' load factor, values of which are typically +9g/–3g for modern fourth generation fighters and for general aviation aerobatic aircraft, +6/-3g. To provide a margin of safety, the aircraft structure is always designed to withstand a higher load than the limit load without failure, this is the 'design' or 'ultimate' load.

The 'factor of safety' multiplier has been used on limit load to determine the ultimate load which provides for rare instances of flight when a load greater than the limit is required to prevent a disaster. Since the early 1930s, the 'ultimate factor of safety' of 1.5 has been utilised by structural engineers as the universally accepted norm. The aircraft must therefore be designed to withstand an ultimate load 1.5 times the design limit load, without failure. Of course, permanent deformation may be expected with this degree of overstress, but no actual failure of the major load-carrying components should occur.

Thus, for a fighter with a limit load factor of 7.5g, the ultimate load factor would be 11.25 g, above which, structural failure could occur. The greatest air loads on an aircraft are usually generated by the production of lift during high g manoeuvres at high airspeeds. At the lower airspeeds, the maximum load factor is limited by the stall, or more technically correct, the ‘lift boundary’. The problem for the display pilot in terms of exceeding the maximum g limit becomes more real as the airspeed increases.

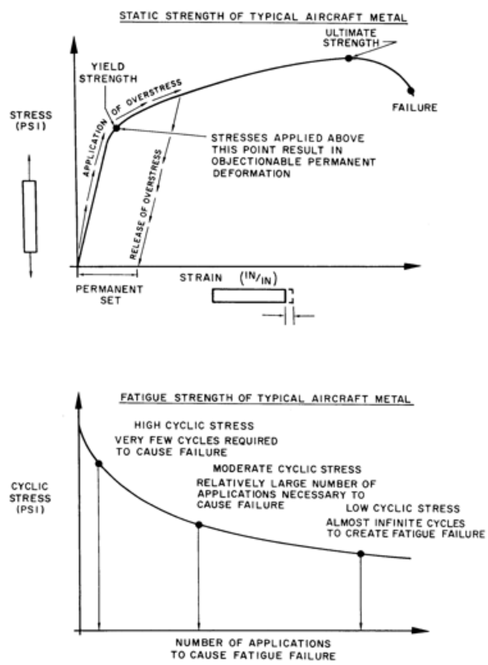
Since the ‘limit load’ is the maximum of the normally anticipated loads, the aircraft structure must withstand this load with no objectionable permanent deformation. The aircraft should be capable of successfully withstanding the limit load and then return to the original unstressed shape when the load is removed. A plot of applied stress versus resulting strain illustrates the typical static strength properties of a metal.

At low values of stress, the plot is a straight line implying that the material is in the ‘elastic’ range and although bending may occur, no permanent deformation occurs since the material returns to its original condition. At higher values of stress, the graph develops a distinct curve in the strain direction as the material incurs disproportionate strains resulting in permanent deformation. The stress defining the limit of tolerable permanent strain is the ‘yield stress’ and any stress applied above this point, produces permanent deformation. Overstressing a high performance aircraft during a display is not too difficult to do as the pilot of a German Air Force F-4 found out during the ILA Berlin on 12 May 2002. During a display manoeuvre, the aircraft exceeded the load limit and in nearly approaching the ultimate load limit, permanent stress damage was incurred, the extent of the damage was considered so excessive, that the aircraft was withdrawn from Service – repair was not considered as cost-effective. If the aircraft is subjected to a load greater than the limit, the yield stress maybe exceeded and objectionable permanent deformation may occur with catastrophic failure possible if the load is greater than the ‘ultimate load’.



Vn diagram for a hybrid aircraft. (Reprinted from Aerodynamics for Naval Aviators by H.H. Hurt, Jr.)

The display environment is particularly harsh on the airframe and the repetition of various aerobatic overloads can produce fatigue in the structure which can generate creep damage. This creep damage is pilot induced and as such, special attention must be given by the display pilot in preventing excessive deformation or creep failure. The fatigue strength requirement is the consideration, given the cumulative effect of repeated or cyclic loads. If a cyclic, tensile stress is applied, after a period of time, the cyclic stressing will produce a minute crack at some critical location. With the continued application of the varying stress, the crack will propagate until the remaining cross section is incapable of withstanding the imposed stress and a sudden final failure occurs. In this fashion, a metal can be failed at stresses much lower than the static ultimate load.



Effects of cyclic stress loadings. *(Reprinted from Aerodynamics for Naval Aviators by H.H. Hurt, Jr.)*

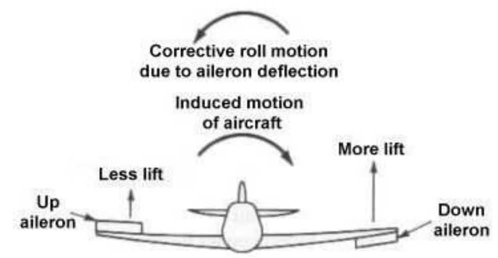
It is exactly what happened in the case of the catastrophic failure of the SAAF’s *Silver Falcons* singleton’s wing during a display at the Africa Aerospace airshow at Lanseria in 1993. The right-hand wing failed catastrophically while pulling out of a 4-g loop, well below the limit load of 7.2g for the specific configuration. The propagation of the crack in the mainspar had progressed unchecked until final failure at a g-loading from which any pilot would have expected the integrity of the structure to be able to handle the load. The loss of life is particularly distressing when structural failure, which is outside of the control of the pilot, occurs. Many pilots may elect not to record overstressing an aircraft but the price will ultimately be paid by someone. It is thus imperative that the display pilot report overstressing because failure to do so could ultimately result in the catastrophic failure of a component at a 'g' value considerably below the specified limit load. Could it also have been a contributory cause to the Pitts Special crash when highly experienced stunt pilot, Clarence Speal, died after the left wings folded entering downline snap rolls at the Three Rivers Regatta in Pittsburgh in 1996?

The principles applicable to the airframe are equally applicable to the engine, in fact, even more so since the engine of an aircraft flying a display is normally subjected to a range of operating conditions outside the design criteria for the engine in many cases. The display pilot's primary concern is to manage the energy level of the aircraft and with the pilot workload already cut out maintaining the show line, minimum altitudes and show centre, there is a natural tendency for display pilots to accord less than the required care on the engine. The throttle position can be slammed from idle to maximum afterburner, from idle to full power, all within the space of a few seconds. The engine temperatures can range from minimum in flight idle to maximum in three to eight seconds – the cyclic fatigue significantly increasing creep damage due to operating temperatures.

The high operating temperatures of gas turbine components provides critical environment for creep conditions which are most crucial at high stress and high temperature and both factors increase the rate of creep damage. The normal operating temperatures and stress of gas turbine components create considerable problems in design and the operating limitations deserve very serious respect by display pilots since excessive engine speed, excessive turbine temperatures or over-boosting the engine, will cause a large increase in the rate of creep damage and lead to premature failure of components. By the very nature of dynamic manoeuvring of an aircraft during display flying, structural loading must be an essential consideration for each of the display's manoeuvres.

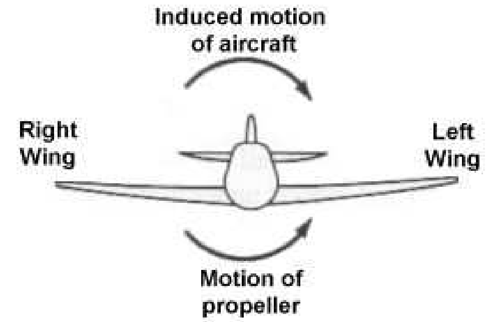
TORQUE

The phenomenon of torque is one of the basic elements taught to student pilots from as early as their first flight. The mechanism is well understood by all pilots but is particularly important to display pilots since it brings to the display repertoire a unique mechanism that can be utilised to generate new manoeuvres and extremely dynamic trajectories. A dictionary of aerobatic flight, first published in 1961, listed every conceivable aerobatic manoeuvre and position defined at that time, 3,000 in all. Today, this list has grown significantly as pilots experiment with the capabilities of their aircraft which demonstrates that aerobatic manoeuvres conform to the natural evolution of flight that has occurred throughout history - as aircraft capabilities continue to improve, skilled pilots learn to exploit those improvements.



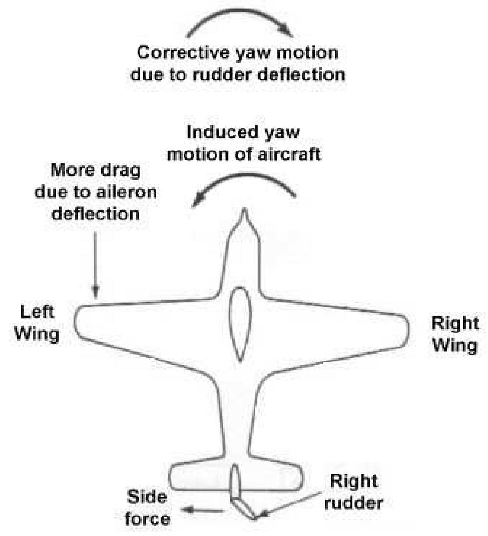
Corrective roll motion created by deflecting the ailerons.

The torque phenomenon originates in Newton's basic Law of Motion which states that: "For every action there is an equal and opposite reaction." Torque is the reactive force generated by a revolving propeller that tends to rotate the aeroplane in a direction opposite to the direction of the propeller rotation. When viewed from the cockpit, most propellers turn clockwise, so the rest of the aircraft has a tendency to rotate anti-clockwise, or left-wing down. The impact of propeller torque implies increased pilot workload on propeller aircraft compared with jet-engined aircraft. In fact, the propeller aircraft's handling characteristics to one side are significantly different than those to the other, depending on the direction of rotation of the propeller.



Torque induced on an aircraft due to propeller rotation.

The same principle is obviously equally applicable to a helicopter. As a helicopter's engine spins the main rotor in one direction, the helicopter body wants to spin in the opposite direction. However, the smaller rotor on the tailboom must generate a force, or more correctly a *moment* that counteracts the induced spin of the body and keeps the helicopter in equilibrium. The purpose of the main rotor therefore, is to lift the vehicle and also provide the thrust for forward motion while the second rotor is needed to counteract what is called the *torque effect* .



Corrective yaw motion created by deflecting the rudder. *(Jeff Scott http:www.aerospaceweb.org)*

While helicopters use a second rotor to address the torque mechanism, on a fixed-wing aircraft this tendency must usually be counteracted by pilot control inputs. Since the aircraft wants to roll to the left, right aileron is required to increase the lift on the left wing to create a right-roll moment. This moment counteracts the rolling motion induced by the propeller torque and returns the aircraft to a wings-level configuration. However, this aileron deflection has the effect of inducing aircraft asymmetry because one side of the aircraft produces more lift than the other. Not only more lift however, but also more drag which consequently increases the drag on the left side of the aircraft causing it to yaw to the left due to as adverse yaw. To correct for this yaw effect, the pilot must thus also apply right-rudder to counteract the adverse yaw and keep the nose pointed straight ahead. All in all, a lot more dexterity required to keep the aircraft in balanced flight during each of the display manoeuvres.

Have you ever watched a high-powered WW II fighter aerobatic aircraft when doing a power check? The left oleo is depressed considerably and the right one is extended. There is also the problem of gyroscopic or precessional force that combines with torque to generate the roll/yaw moment. In the case of a right turning propeller, a force applied to a spinning propeller occurs 90º to the direction of rotation. Incidentally, this is also the force that when properly executed, causes an aircraft to perform the weird gyrations of the Lomcevak which is essentially the same force during takeoff in a tail dragger that causes the aircraft to veer to the left when the tail is lifted.

The torque effects can be completely eliminated on multi-engined propeller driven aircraft by using propellers that rotate in opposite directions. By rotating the right engine clockwise and the left engine counter-clockwise, for example, the torques cancel each other. Any rotating component creates asymmetrical forces and moments on an aircraft, even the rotating fans and turbines in modern jet engines will do so, but these effects are usually so small that they are not significant to pilot handling in most conditions. Modern flight control systems correct for these effects automatically through automatic trimming systems.

Three forces generate the left-turning tendency of the single engine piston aircraft i.e. torque, slipstream and gyroscopic precession. When the aircraft is thus pulled-up out of a dive or the engine power increased, it generates a left roll and yaw tendency (propeller turning clockwise viewed from the cockpit). Pushing-over into the dive or decreasing engine power, reverses the forces acting on the aircraft and the force becomes a right-turning tendency. Such forces are obviously reversed if the propeller turns anti-clockwise.

Evolving directly from the early air racing and military training aircraft, the initial aerobatic aircraft were usually oversized but underpowered and produced rather lacklustre aerobatic performances by today's standards since aircraft manoeuvrability was sluggish and the ability to climb vertically was limited. In spite of equipment refinements that allowed inverted flight capability such as upgraded airfoils, fuel, and oil systems, even the best aerobatic aircraft cannot fly for long periods in unnatural flight attitudes. These aerodynamic limitations are such that no aerobatic aircraft in existence can efficiently fly on its side, the glowing claims of "knife edge" climbs or spins notwithstanding.

Engine torque and slipstream from a spinning propeller causes an aircraft to respond differently when manoeuvring to the right than it does to the left, forcing aerobatic pilots to have to learn their manoeuvres in both directions. Any manoeuvre in which pitch attitude is increased or power is increased, induces precession coupled to subsequent roll and yaw to the left. The higher the power setting, the more destabilising the effect. Taken a step further in manoeuvring, significant dexterity is thus required by the display pilot in flying particular manoeuvres such as the stall-turn, aileron rolls, spinning etc, the impact of torque, slipstream and P-factor can have significant adverse effects.

The magnitude of the phenomenon is dependent on the power produced by the propeller which is a function of engine size. Roll performance of an aircraft can be significantly supplemented by engine torque if the roll is in the same direction of the torque effect. However, it is not just a simple matter of applying maximum aileron, adverse yaw could couple the manoeuvres and could lead to departure or even structural failure due to high lateral or sideslip loads. Manoeuvres thus need to remain balanced. The vintage F4U rolled well but when rolling in conjunction with powerplant torque, in other words, rolling left, it was among the very fastest rolling fighters of WWII. In the inventory of American fighters, only the P-47N rolled faster, and only by 6º/sec. (Jeff Scott http:www.aerospaceweb.org)

In the mid-1970s, heavier aircraft with more powerful engines, more inertia and more precession force, generated a sudden upsurge in tumbling manoeuvres that continues to the present day. The variations are apparently endless, so much so that airshow pilots have either given up on naming them all, or simply can't remember what it is that they just did because of the brain-scrambling effects of high-G.

Around 1972, American and world aerobatic champion and well-known airshow pilot Charlie Hillard invented the Torque Roll, an aerobatic manoeuvre that uses the torque reaction to generate roll rate. It basically consists of entering what looks like a Tail Slide, and then hanging the aircraft on the prop while initiating a continuous roll to the left. With a right-turning propeller, engine torque keeps the roll going until the aircraft begins to slide back, whereupon aileron is immediately reversed (because the direction of flight is now reversed) to keep the left roll going.

Although in the tail slide torque roll, opposite aileron input is used, the speed of the tail slide is so slow it will torque even if the ailerons are not reversed, torque force rolling the aircraft even further. When this happens, the only way to prevent the airplane from rolling is to reduce power. Recovery is accomplished by closing the throttle and finishing as in the Tail Slide. The very clever, 'Zwilbelturm', or 'Spiral Tower' was invented in 1974 by Swiss and European champion Eric Muller. From a right roll on a vertical up line, a tumble is begun that resembles an inverted ascending spin. The controls are reversed to accomplish a transition to an upright flat spin as the aircraft reaches apogee and starts to descend.

With the worldwide increase in formally judged aerobatic competitions, the primary focus has shifted back to the European pre-war emphasis on flying standardized figures with geometric precision. This competitive paradigm shift excluded gyroscopic figures such as the Lomcevak, since the aircraft and the pilot response varied so much that establishing precise judging standards for tumbling manoeuvres was impossible - simply describing some of the figures in Aresti environ is impossible! However, the gyroscopic tumbles and Torque Rolls were far too popular with competition pilots and spectators to simply be discarded or relegated to non-competitive venues. They became the centrepiece of the modern Four-Minute Freestyle event which is judged by standards similar to those used by the Lockheed Trophy and remain the cutting edge of aerobatics, where today's pioneers may still discover new forms of aerobatic flight.

However, the *torque-roll* has caused many accidents when the pilot entered this unfamiliar flight regime inadvertently. A sudden increase in power not only generates a sudden increase in roll/yaw coupling, but the pilot's reaction and response times may not be capable of compensating for the ensuing motions. Complicating the issue even more is that many display flight phases are conducted at relatively low speeds. When the speed of the airflow passing over the aileron and rudder is slow, these surfaces lose much of their effectiveness and may not be able to counteract the torque. It is not impossible for the pilot's response to lag the torque induced roll/yaw moment with a resulting pilot induced oscillation as the pilot attempts to bring the torque moments under control. At low-level and low airspeed, there may not be the luxury of height and time to recover, the end result could be catastrophic. However, under the hands of a professional, well-practiced aerobatic pilot, the torque roll can be put to good use in any airshow routine.

What contribution did torque have on the airshow accident that killed pilot Carey Moore when his Hawker Sea Fury crashed while performing at the Sarnia International Airshow in Ontario in July 2001. The Sea Fury engine produces approximately 2,400 HP which, if selected at low airspeed, would most certainly roll the aircraft uncontrollably. Eyewitnesses in fact reported seeing the aircraft enter an incipient spin after doing a climbing turn from a slow, low-level pass.

Interestingly, torque as an aerobatic nuance dates back to 1945 as the face of aerobatic flying was changed forever when Curtis Pitts built the first aircraft specifically designed for aerobatics, the Pitts Special S-1. Pitts envisioned an aircraft that could disobey gravity and respond crisply to its controls; a smaller aircraft than the war-era biplanes but one that could climb and roll with agility. Pitts abandoned the concept of a large radial engine and designed an aircraft powered by a smaller, lighter, horizontally-opposed engine with an aft centre of gravity that allowed for tight snap rolls. The resulting Pitts line of aerobatic aircraft, small, with only a 17-foot wingspan, lightweight, and extremely agile with high power-to-weight ratios, soon dominated aerobatic competitions.

An aerobatic kit plane, the Stephens Akro, inspired similar monoplane designs that overcame the Pitts' major design drawback, the inability to climb vertically. The lower drag from the single wing configuration translated into higher airspeeds and although airspeed is not a necessity for an aerobatic aircraft, it is highly desirable since it can be translated into altitude quickly. The Akro-derived aerobatic designs were quickly overshadowed by specialized aircraft, such as the Extra 300 that continued the evolution process by incorporating design refinements that separated them from other conventional light aircraft. Increased structural strength including the use of composites, more powerful engines, larger propellers, improved aerodynamic surfaces and controls have yielded aircraft that are well suited to the demands of aerobatic flight. The Stephens Akro inspired the present generation of Unlimited monoplanes such as Laser 200, Extra 300, and Superstar.

Torque is what turns the propeller, and if it is to be used for manoeuvres in the routine, it is essential for the display pilot to know how much torque is available and at what RPM. If for example, maximum torque is developed at 3,000 RPM, the tip speed of a very long propeller will be supersonic and probably create more drag than thrust while also having some undesirable effects on the portion of the blade that is just at the speed of sound. If maximum torque is developed at a very low engine RPM, a longer blade may be more desirable, however, ground clearance will have to be considered and with longer blades there will be more outside noise, but not necessarily more noise in the cockpit.

Another peculiarity of torque is the cross-coupled effects that it produces, for example, the stall turn (hammerhead stall). Why does the display pilot need to apply opposite aileron when doing a stall turn to the left? Well besides the outside wing developing slightly more lift, there is the gyroscopic effect rolling and yawing the aircraft. How is this phenomenon manifested in jet aircraft, without the contributions from engine torque, slipstream and precession? Since any rotating mass is in essence a gyro, there is a gyroscopic force produced in a high-speed jet turbine but obviously not the 'P-factor'. But because jet aircraft do not have any propeller slipstream on the rudder, the display pilot has to kick the rudder to yaw the aircraft around a point while it still has reasonable forward speed. At zero airspeed the rudder is absolutely useless on a jet since there is no airflow over the rudder surface. When a jet does a stall turn, it is thus not a zero airspeed manoeuvre as it is with the propeller driven aircraft. If the rudder is effective on a jet, then so are the ailerons, and under this condition the outside wing has considerable lift and has to be negated by the use of aileron.

Improved control during stall, snap roll, and spin manoeuvres cannot completely offset the effects of engine torque. An aerobatic aircraft with sufficient thrust to briefly “hang” on its propeller for a moment is soon overcome by engine torque that, in turn, rotates the aircraft. The skilled aerobatic pilot understands these design limitations and learns never to yield control of an aircraft during an aerobatic manoeuvre.

GUST RESPONSE

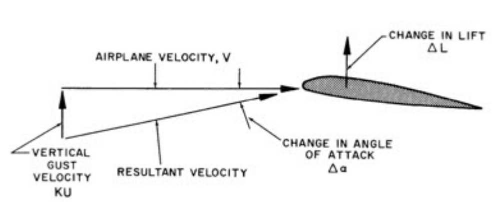
To the crowd camped in the spectator enclosure, none of the effects of environmental factors are noticeable, yet the unseen elements continue to influence the trajectory of the aircraft. Only when one takes a closer look at the formation aerobatic teams or the smoke trail from an aerobatic aircraft, is it sometimes possible to detect the effects of atmospheric disturbances caused by winds, temperature or orographic features. Turbulence is particularly irritating to the display pilot operating so close to the earth’s surface manifesting itself as bumpy atmosphere but more technically, as gust response. Turbulence not only increases pilot workload, but also increases the physical effort and pilot fatigue of flying an aircraft.

The amount of lift force that an aircraft can generate is dependent on how fast the aircraft is flying. At slow speeds/high angle of attack, the maximum available lifting potential of the wing is relatively speaking already nearly saturated and is equal to the amount necessary just to support the weight of the aircraft; there is very little spare capacity to generate large amounts of additional lift. Consequently, if the elevator was pulled back sharply at or near the maximum angle of attack, the additional load factor would not be excessive. Alternatively, if the aircraft encountered a severe vertical gust, the load factor generated would not be excessive and the aircraft would most probably stall before the loading could become excessive.

However, at high speeds the situation changes dramatically; the potential of the wing to develop lift force is now so great that any sudden movement of the elevator controls or a strong gust, could increase the load factor beyond safe structural limits. Although not directly associated with gust response, there is a subtle nuance in aircraft response which is particularly noticeable on the earlier generation aircraft with non-computer controlled flight control systems. It has for long been one of the traps for the display pilot.

It is not uncommon for display pilots to elect to finish their show routines with the more dramatic maximum allowable, high-speed pass at low-level followed by an ‘upward Charlie’ or vertical rolls. Considering an aircraft such as the Dassault Mirage F1, the final run-in would typically be flown at 600KTAS/M0.92 and due to the very large turn radius at such a high speed and in an effort to produce a ‘square corner’ effect at the pull-up, a high level of pilot skill is required to initiate the pull-up from 1g to 6g in approximately one second. The pull-up at such high airspeeds needs to pretty sharp to provide the spectators with a picture of a ‘square pull-up’. However, if the pilot is not focussed or misjudges the pull force, the rather rapid pull required at such high airspeeds can easily ‘over-rotate’ the aircraft and exceed the pitch rate limitation and possibly induce a ‘snap over-g’ which results in the aircraft being rendered unserviceable while the time-consuming over-g checks are conducted by maintenance.

The over-g inspection is a lengthy and comprehensive rigging check to assess any degree of bending or buckling stresses. The dangers of continued over-g can obviously result in permanent bending and ultimately catastrophic failure due to the cumulative effects of overstressing. This phenomenon is additionally problematical for aircraft with aft CGs and could even result in aperiodic pitch divergence. This handling problem is alleviated by the computer controlled flight control systems of the late third and early fourth generation aircraft.



The vectorial addition of the gust velocity to the aircraft velocity causes the change in angle of attack and lift. *(Reprinted from Aerodynamics for Naval Aviators by H.H. Hurt, Jr.)*

Turbulence in the form of vertical air currents can, under certain conditions, cause severe load stress on aircraft structures, particularly the lifting surfaces. The horizontal gust only produces a change in dynamic pressure, but a vertical gust induces changes to the aircraft angle of attack. When an aircraft is flying at a high airspeed (low α), and suddenly encounters an upward vertical current, the relative wind increases the angle of attack of the wing. The loads experienced when the aircraft encounters a strong gust can exceed the manoeuvre limit load in somecases. The structural engineering standard vertical gust is defined at 30 ft/sec at maximum level flight speed which theoretically produces a 3-g load factor on an aircraft but for structural certification purposes, however, the vertical gust is reduced to 15 fps at maximum dive speed. A sharp vertical gust will have the same effect on the wing as applying sudden sharp back pressure on the elevator control.

where
U = sharp gust velocity (ft/sec)
V = TAS (ft/sec)
P = air density (slugs/ft^3)
$C_{L\alpha}$= Lift curve slope of the wing (rads)

An aircraft manoeuvring dynamically encountering turbulence, can be subjected to an increase in load factor ranging from –1.5g to +3.5g. All certificated aircraft are designed to withstand loads imposed by turbulence of considerable intensity, but, the flying of low-level aerobatics in uncertified aircraft under high turbulence conditions, can become especially hazardous. The numerous recorded cases of structural fatigue at airshow accidents are well documented in Chapter 2 and 3 and the accident aircraft categories extend from prototype fighters to front line fighters.

The incremental change in load factor, due to gust response, can be basically expressed as:

$$\Delta n = \frac{\Delta L}{W} = \frac{\rho U V C_{L\alpha}}{2W / S}$$

The effect of over-g is not only pertinent to pull-ups and push-over's, but also to the effect of vertical gusts and because of the relationship between airspeed and structural integrity, certain maximum speeds have been established by engineering for dynamic manoeuvring. As a general rule, when severe turbulence is encountered, the aircraft should be flown at the design manoeuvring speed, V_a as stipulated in the Aircraft's Flight Manual or placard in the aircraft. This is the speed least likely to result in structural damage to the aircraft, even if full control deflection is applied and additionally allows a sufficient margin of safety above stalling speed in turbulent air.

Since gust load factors increase with increasing airspeed, it is prudent, in strong turbulence, where feasible in the show routine, to reduce the airspeed to the design manoeuvring speed – provided it has been practiced for. But this is not usually possible during a display; what is possible though, is to loosen the show routine to prevent the incremental g due to turbulence.

The design of the aircraft and in particular the lifting surfaces exert a powerful influence on the gust increment. The lift curve slope relates the sensitivity of the aircraft to changes in angle of attack – the higher the aspect ratio of the aircraft, the more sensitive the aircraft is to turbulence. The effect of wing loading on the other hand, can be misleading. Ironically, the induced load factor due to a gust increases if the aircraft is lighter, which is contrary to the natural assumption that an aircraft is more likely to experience structural failure if it is heavily loaded. If the aircraft is lighter, the same lift increment will cause a greater vertical acceleration (load factor) so the aircraft will experience greater stress loading. For maximum performance, Most display pilots elect to reduce the display weight to the absolute minimum in an effort to increase the T/W or SHP/W ratios. So in turbulent conditions, although the display pilot may find that the lower all-up-weight improves performance, the ride qualities in the turbulence degrade.

Why is this important to the display pilot? It is clear that the factors directly affecting the incremental g-loading due to turbulent gusts are the true airspeed, the air density and obviously the lift curve slope of the wing. The factor reducing the effects of gust induced incremental g-loading, is the wing loading, the higher the wing loading, the lower the incremental g-load that can physically be generated. Placarded *never exceed speeds* are determined for smooth air only and it is prudent for the display pilot to consider the effect of high diving speeds or abrupt manoeuvring in turbulent air at airspeeds above the manoeuvring speed since such loads may place damaging stress on the whole structure of the aircraft.

WAKE VORTEX

The UK's AAIB published the findings of the accident investigation of the Vampire that 'flicked-in' while trailing the Sea-Vixen at the Biggin Hill Airshow on 2 June 2001. It was concluded that the most probable cause of the Vampire's departure and spin, was the inadvertent entry into the Sea-Vixen's wake vortex. The show routine for the two-ship formation included runs along the crowd line with the Vampire in echelon starboard and then line astern to the Vixen. At the end of the second run, the pair turned away from the crowd with the Vixen carrying out a wingover to the right positioning for a return to the display axis. The Vampire was supposed to carry out a similar manoeuvre but to delay its turn to create a separation with the Vixen of approximately 3,000 ft.

The Vixen executed its starboard turn at about 220 KIAS, pulling approximately 2.5g. The Vampire moved out to port from its line astern position and flew a wider radius to generate the separation before carrying out its own wingover to starboard. As it banked through the 80º offset position to commence the wingover and at approximately 1,500 ft agl, the Vampire continued to roll to starboard, rolling inverted and entering an increasingly steepening descent as the nose pitched down towards the ground. The aircraft then rolled to a wings level attitude transiently while its angle of attack increased rapidly. The roll to starboard however, continued as the Vampire continued downwards, impacting the ground at approximately 200 KIAS in a 45º nose-down, 90º right wing low attitude.

Having found himself in an inverted attitude, pitched down by some 56° below the horizon, the pilot appeared to have arrested the pitching moment, stabilised the aircraft and immediately initiated a roll by applying maximum aileron deflection to recover to the 'nearest horizon'. This was achieved, albeit still with a low nose down attitude. As the aircraft rolled rapidly towards the wings level attitude the pilot would have been faced with the need to apply a large nose-up pitching moment to recover from the dive and at the same time arrest the rolling momentum by applying some degree of opposite aileron.

Amazingly, from the frame-by-frame video analysis of the accident, it was calculated that only five seconds had elapsed from the time that the wingover was commenced until impact with the ground. The pilot had managed to regain partial control to command a transient wings level attitude after 3.2 seconds, however, the Vampire continued to roll to starboard at a measured roll rate of approximately 112º/second.

The wake vortex of any aircraft is comprised of three elements, the engine or propeller slipstream, the aircraft wake and the wing tip vortices. The engine or propeller slipstream is a fairly narrow core, the intensity of which is a function of the engine thrust setting and dissipates fairly rapidly aft of the aircraft. The aircraft wake results from the airframe itself, more particularly from the perturbations generated by components on the aircraft and is usually manifested by turbulent flow shed from the aircraft itself. Finally, the wings produce a vortex sheet which comprises the 'rolled-up' wing vortices shed from the wing which invariably pool up at the wingtips creating the wingtip vortices.

The wingtip vortices are occasionally visible and manifested by condensation of the moist air in the low pressure core of the vortex. The intensity of the vortex is a function of the lift being generated by the wing, which in turn is a function of the mass of the aircraft or the 'g' being pulled. The vortices, due to the spanwise flow of the air over the wing, rotate clockwise (when viewed from behind) on the right wing and anti-clockwise on the left wing. This wake vortex can produce a significant rolling moment on any formating aircraft that is caught in the vortex sheet – if the aircraft are dissimilar types such as the Vampire and the Sea Vixen, the lighter Vampire could experience severe rolling moment forces from the much heavier Sea-Vixen.

At the moment of departure and from measurements made from the video analysis, the Vampire was calculated as trailing the Vixen at approximately 550 ft (170m). Besides the greater mass of the Vixen, the Vixen's effective mass would have been increased by at least 2.5 times due to the g being pulled in the turn, making for severely intense wake vortex. The vortex generated by the Vixen would thus have been three to four times that produced by the Vampire and would in theory, be capable of generating roll rates of 70º/second on the Vampire. Under the prevailing conditions of airspeed and g, the roll rate generated by the Vixen's vortex sheet exceeded the roll power of the Vampire, which in turn would account for the aircraft rolling inverted nearly immediately on entering the Sea Vixen's slipstream.

AAIB calculations concluded that the vortex dissipation at 500 ft was insignificant and that although the pilot had nearly managed to command wings level from the inverted attitude, the steep nose down attitude required a large pull force by the pilot to recover from the dive. However, with the combination of high angle of attack, the inherently high wing loading of the Vampire coupled to the adverse yaw of aileron and rudder inputs in trying to recover the aircraft, the Vampire entered an accelerated stall, flicking to the right as it continued on a downward trajectory. Many a Vampire pilot has no doubt experienced the 'flick' of the Vampire during hard turning in air combat manoeuvring training. With adequate height margins, recovery was usually possible but at such low altitudes as that flown at Biggin Hill, there was an extremely low probability of safe recovery from the uncommanded departure.

In late 1969, Dryden Flight Research Centre pilots began investigating wake vortices by flying an instrumented F-104 fighter behind a B-52 bomber and C-5 transport. The C-5's vortices were so strong that on one flight, the F-104 was rolled inverted and lost 3,000-4,000 feet of altitude even though the fighter was flying ten miles behind the larger aircraft. Wake vortex could also have contributed to the hard landing of the 'slot-aircraft' in the nine-ship *Snowbirds* formation in April 2001. The hard landing resulted in the collapse of the right undercarriage and nosewheel.

Although the effect of wingtip vortices is not normally a large problem in similar type aircraft formation displays, there are a number of particular factors in this instance that suggested that the vortices shed from the Sea Vixen might have played a part in the accident. These factors included the large disparity in operating weights between the Sea Vixen and the Vampire and the fact that both aircraft were banked in a turn, thus generating additional wing lift and thus vortex strength at the time that the Vampire departed from its expected path. The two aircraft were separating and the strength of trailing vortices may be considered as developing gradually behind a wingtip ('rolling up') to reach full strength some two to four wingspans behind the generating aircraft, then maintaining this intensity for at least 80 to 100 wingspans.

Because of the possibility of a wake vortex encounter, the AAIB commissioned an aerodynamic study to determine the degree to which the trailing vortices from the wingtips of the Sea Vixen might have influenced the flight path of the Vampire. To judge the strength of the vortex field, the 'horseshoe vortex approximation' was used and although this did not include modelling of vortex dissipation, it was considered that at a spacing of 150 metres, no significant dissipation would have occurred. The Sea Vixen was modelled as having a mass of 14,784 kg (Max AUW 18,858 kg) and flying at 270 kts in a 2.5g turn. The Vampire was given a mass of 4,400 kg (Max AUW 6,124 kg) at 220 kts in a 2.0g turn. Longitudinal displacement of 150 metres between the two aircraft was used and the Vampire was placed 6.7 metres to the left of the Sea Vixen's centreline.

With these assumptions the modelling showed the vortex circulation of the Sea Vixen as being three to four times stronger than that of the Vampire. It also concluded that the vortices could generate roll accelerations exceeding $70°/sec^2$ in the Vampire, probably greater than the counter roll authority available to the Vampire at that speed. The modelling also suggested that, if the Vampire stayed close to the vortex core, its roll rate could possibly reach as much as 200°/sec. This would be very unli kely, however, since the Vampire's interaction with the vortex from the Sea Vixen would only be transient as the flight paths diverged. The aerodynamic study further suggested that a rapid roll to the right of 90° by the

Vampire, as actually occurred in this particular accident, would be a likely result of such a vortex wake interaction.

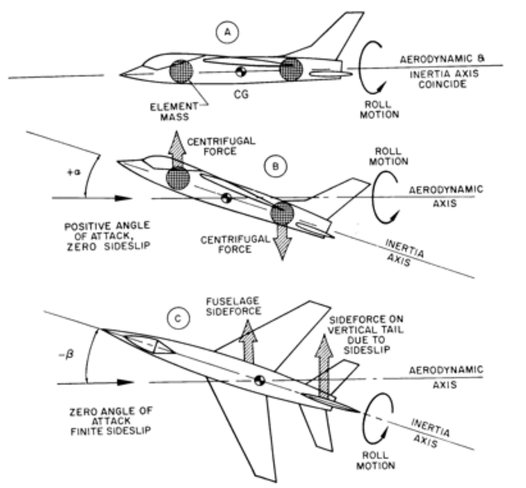
Further evidence of this was suggested in a study carried out by the Armament Department of the Royal Aircraft Establishment in 1954. The tests were to determine the position of the wake of a target aircraft and its general effect on a tracking aircraft. Extracts from the test paper (Technical Note No Aero. 2283) study considered the wake behind a jet aircraft as having different components. The jet efflux which consists of a small diameter region having a longitudinal velocity combined with perhaps a relatively small rotation due to swirl. Considerable small-scale disturbances would be expected to be present and the body of other wakes which are characterised by regions of turbulence and reducing total head pressure behind drag producing components. In most cases the largest region would be behind the fuselage. The vortex sheet and trailing vortices shed from the wing rapidly rolls up into a pair of trailing vortices while small scale disturbance is confined to the cores of these vortices.

Tests were planned in such a way as to investigate each of the above components separately, an attempt being made to measure the magnitude of such components as well as their rate of decay with distance behind the aircraft. A Meteor Mk 4 aircraft (AUW approximately 6,900 kg) was used as the 'target' with a Vampire Mk 4 as the trailing aircraft. Measurements showed that the 'jet velocity' (jet efflux) fell to a negligible value by about 200 to 300 feet behind the jet exit. The results showed that the vortices persisted for a considerable time and had decayed to only half of their initial strength by 8,000 feet behind the target. For the two speeds (188 kts and 235 kts) at 30,000 ft to 35,000 ft altitude, the disturbances close behind the aircraft were so strong that although maximum stick travel was used, the wings could still not be kept level.

Wake vortex and aircraft slipstream effects have been the cause of many aircraft accidents in both general and military aviation. But, wake vortex is a given, a natural phenomenon associated with lift production and within current aerodynamic design constraints, will continue to provide a hazard to display pilots – a hazard that becomes more critical the lower the aircraft is above surface level.

ROLL COUPLING

The pursuit of high speed flight led aircraft designers to focus on streamlined fuselage shapes in which mass was blended into elongated fuselages and swept back wings and fins suffered reduced aerodynamic authority. This in turn led to reduced aerodynamic stability and damping contributions from the empennage and mass redistribution to the wings moving further outwards from the CG. The appearance of 'roll-coupling' problems was the natural result of the progressive change in inertial characteristics induced by the aerodynamic requirements of mainly high speed aircraft design.



Inertial cross coupling forces. (Reprinted from Aerodynamics for Naval Aviators by H.H. Hurt, Jr.)

This 'coupling' mechanism is produced when a disturbance about one of the aircraft's axes, produces an inertial disturbance about one of the other two axes of the aircraft. If the inertia axis is inclined to the aerodynamic axis, rotation about the aerodynamic axis will create offset centrifugal forces that generate a pitching, cross-coupled moment. The most common form of cross coupling which all pilots encounter on a day to day basis is that of the roll associated with rudder deflection, 'yaw induced roll' to be exact and although not inertial but rather 'aerodynamic coupling', the principle remains the same. And then there is also adverse aileron yaw that produces a form of aerodynamic coupling, the drag of the down going aileron (acting about the longitudinal axis) inducing a yawing motion about the normal axis.

Although not inertial cross-coupling, this phenomenon can be particularly hazardous at low level during low-level aileron rolls in earlier generation and vintage design aircraft. The most important consideration for the display pilot during low-level aileron rolls is to ensure that the nose of aircraft stays 'pegged' above the horizon. The effect of the adverse aileron yaw is to pull the nose off and away from the horizon which means that the display pilot must aggressively ensure the nose position through coordinated use of pitch and rudder controls.

There are two axis systems to each aircraft, the inertial axis through the CG in the direction of the two element masses, and an aerodynamic or wind axis system through the CG in the relative wind direction. The inertial axis is a fixed axis system for a given inertial distribution and in the longitudinal plane would typically run closely to the longitudinal axis of the aircraft. The aerodynamic axis is not a fixed system and varies as a function of the angle of attack.

For an aircraft rolling about the inertial axis that is displaced from the aerodynamic axis, after 90º, the angle of attack (alpha) becomes the angle of sideslip (beta). Also, the original zero sideslip has become the zero angle of attack. The sideslip induced by the 90º displacement will affect the roll rate depending on the amount of dihedral on the aircraft. Important to note is that the initial inclination of the inertia axis above the aerodynamic axis, will cause the inertia couple to provide adverse yaw with rolling motion. If the inertia axis were initially inclined below the aerodynamic axis as in the case at negative load factors at very high indicated airspeeds, the roll induced inertia couple would provide proverse yaw. As a result of the aerodynamic and inertia cross coupling, rolling motion can induce a great variety of longitudinal, directional and lateral forces and moments.

In summary, inertial cross-coupling results from the inertial distribution in pitch, roll and yaw. The high-speed, long, slender fuselage aircraft with short, thin wings produces a roll inertia which is quite small in comparison to the pitch and yaw inertia. On the other hand, the lower speed, older vintage aircraft may have a wingspan longer than the fuselage length which produces a relatively large roll inertia.

The impact of inertial cross coupling on display flying is mainly in limiting the display potential of the aircraft, mainly in the rolling plane. For example, most third generation fighter types of the long slender design, have roll limits in terms of Mach number and the number of consecutive rolls. Mostly, consecutive rolls are prohibited or not recommended by the Manufacturer, single rolls only. To the spectator on the ground, the weaker stability contributions at higher Mach can be visibly seen during the low-level rolling displays in which the first roll is essentially around the aerodynamic axis but as the rolling motion progresses, it appears as if the tail loosens up and some form of 'snaking' or wandering becomes evident. This creates the unusual impression to the spectator that the aircraft is no longer rolling about the longitudinal axis but rather 'corkscrewing'.

In fact, all aircraft exhibit aerodynamic and inertial cross-coupling to varying degrees but usually present no problems because the inertial moments can be counteracted by the aerodynamic restoring moments generated by the inherent stability of the aircraft. However, whether the aircraft motion diverges directionally or longitudinally, is of academic interest only to the display pilot. More importantly though is that if inertial coupling exists and it is divergent, it can have catastrophic effects as the aircraft breaks up in-flight.

Pitch and yaw auto-damping systems are fitted to an aircraft susceptible to inertial cross-coupling to damp out pitch and yaw accelerations thereby helping to prevent aperiodic divergence. Aircraft limitations are also imposed by limiting maximum roll rate, the duration and number of rolls, angle of attack and load factors for performing rolling manoeuvres. The prudent display pilot heeds the limitations imposed by potential roll coupling and resists the temptation to exceed the manufacturers limits in an effort to provide a spectacular display.

EJECTION

Fatal airshow crashes, particularly those of the frontline jets and warbirds equipped with ejection seats, often raises the question as to why pilots continue to lose their lives by not ejecting in the face of impending catastrophe. "Why didn't the pilot eject when he knew that he was in trouble and that he was not going to make it?" Two particular examples in 2000 were the F-14 'wave-off manoeuvre' at Willow Grove, USA and the Aero L-39 solo display at Eastbourne, UK - both were flown by highly experienced display pilots, yet there was no ejection.

From a slightly different perspective and in a different category, two F-86 crashes in the USA, one in California in 1993 and one in Colorado in 1997, were also cases in question, but for different reasons. Although modern military jets are equipped with ejection seats, this is not necessarily true for the civilian owned vintage jets. Since the flight-into-terrain accidents of the two F-86's were ex-military aircraft, it was generally assumed that the aircraft, being fully representative restorations of the original, would still possess an ejection capability. This, however, was not strictly speaking, true. There are thus two distinct cases here, the vintage jets and the front line fighter – some vintage jets fitted with, and some without, ejection seats.

Considering the geometry and dynamics of low-level aerobatics, an ejection seat is mostly outside the ejection envelope at the low heights, the high downward vertical velocity vectors and extreme attitudes associated with display flying. In fact, a large percentage of the display time is taken up by unusual attitudes and the aircraft is within the seat ejection envelope for only a small amount of time during the display. The Achilles' heel is that in certain critical phases of the display routine, particularly in cases where the pilot has 'overcooked' a manoeuvre, high closure rates with the ground and excessive 'life-threatening' peripheral cues may saturate the pilot's decision-making processes. The decision to continue the manoeuvre or to eject is often measured in milliseconds and any delay in the decision making process can be fatal. Considering the capabilities of and the performance shortcomings of the earlier generation ejection seats in this extremely demanding environment, the pilots could just as well have flown with the ejection seat pins still installed in the seat.

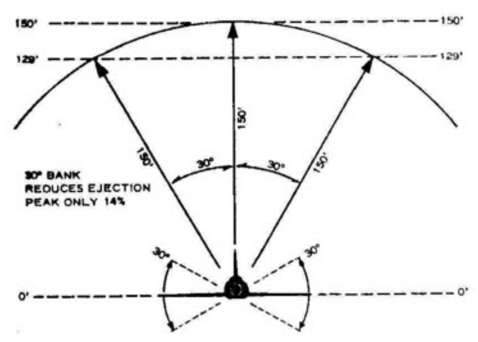
Going back in history, the first USAF emergency ejection occurred in 1949 when a second lieutenant ejected from an F-86 that experienced flight control problems. The aircraft was in a rolling vertical dive passing about 1,000 feet above ground level when the pilot ejected. Although he became entangled with the parachute risers, he survived and became the first crewmember to use an ejection seat. Later that year, another pilot made a successful ejection and joined the select group of airmen who had used an escape system to abandon an aircraft, which of course brought the total ejection attempts in 1949 to two, giving the USAF an ejection survival rate of 100%, a rate never equalled again. Less than ideal survival rates have continued despite the fact that the automatic escape systems have undergone constant improvement since their inception.

In the sample of 118 airshow accidents analysed in Chapter 3, there were ninety-three opportunities for ejection but only thirty-six (39%) aircrew ejected while fifty-seven (61%) did not. The question is, "why the significantly large disparity of 39:61 between those ejecting and those not ejecting?" The answer most certainly lies in the dynamics of high closure rates versus the human's questionable decision-making capacity under duress and the relatively slow reaction times, both which contribute strongly to this phenomenon.

Of the thirty-six ejections, twenty-four (67%) were successful while twelve (33%) were unsuccessful. What is pertinent to note is that most of the ejection sequences in which the aircrew survived, were initiated in a relatively wings level attitude with a positive climb vector or at worst, a low descent rate. Of the twelve that were killed in the ejection process, eight ejected outside the ejection seat envelope while in two cases, the aircrew landed in the post-crash fireball because of the low altitude at ejection.

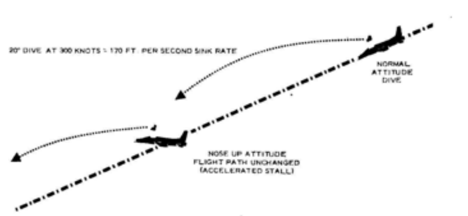
Statistically speaking, it is difficult to quantify the survival rate of display flying ejections exactly, but, based on the analysis in Chapter 3, in a low-level display aircraft without excessive rate of descent or bank angle, a pilot probably has on average, a 67% chance of surviving a low-level ejection providing the decision to eject is made timeously. What must be remembered is that ejection is not a benign procedure, ejection seats are not a panacea for all ills, and they too have their limitations.

The more modern ejection seats such as the Martin Baker Mk 10 seat and later versions, are capable of successfully ejecting the pilot from an inverted aircraft flying level at 250 ft and 200 kts. That in itself is pretty impressive performance but even with such performance capabilities, the very high rates of descent and the extreme roll attitudes are far in excess of what the seat can handle and pilot survival probability following ejection during low-level manoeuvring, is not high. This, in spite of the spectacular successes of the Russian Zvezda ejection seat performance demonstrated by the two MiG-29 ejections at RIAT 1993, the Su-27 at Paris Airshow in 1996 and the most spectacular to date, the Ukraine Air Force Su-27 at the Lviv Airshow in 2002.



Effect of bank angle on ejection seat performance. (USAF Aerospace Safety Magazine, "Precious Seconds", Capt R. A. Anderson)

Amongst display pilots there is obviously concern over the effects of altitude on ejection seat performance as well as some implications attributed to aircraft roll and pitch attitude at ejection, comment is thus required. Analysing the geometry of an ejection trajectory, it becomes apparent that only once the pitch or bank angle exceeds 30° that the effect becomes significant and until that angle, in theory at least, the effect is generally not as unfavourable as theory would have one believe. Illustrated is the effect of a 30° variation from the vertical, the peak height is reduced by 14% at 30° bank angle. Thus, a seat that would eject a pilot 150 feet high from straight and level flight, would eject the pilot to only 129 feet, 21 feet less. That said, the probability of ejection survival at low-level is often only a matter of feet and therefore, relatively speaking, 21 feet does become significant in the real world since it could certainly mean the difference between life and death or injury.



$V_{\text{ejec velocity}} = V_{\text{a/c vert velocity}} + V_{\text{ejection seat}}$

Effect of pitch attitude and vertical descent rate on ejection seat performance. (USAF Aerospace Safety Magazine, "Precious Seconds", Capt R. A. Anderson)

Considering the vertical, when ejecting from an aircraft in a 30° pitch attitude, the effects of flight path, more particularly the vertical airspeed on the overall ejection velocity, is almost invariably far more significant than the effects of aircraft pitch attitude on the seat. This is due to the fact that the resultant seat ejection velocity at the time of ejection is the sum of the seat's vertical velocity plus the vertical velocity of the aircraft. An aircraft in a 20° dive at 300 knots descends at a sink rate of 170 ft/sec (10,200 ft/min) and for an ejection seat end-of-gun velocity of 80 ft/sec (4,800 ft/min) this results in a nett descent rate of –90 ft/sec. The math will tell you that unless there is a healthy band of height below the aircraft, the end result could be catastrophic for the pilot. To illustrate that it doesn't go so much about attitude here, consider the case if a pilot in the 20° dive pulled back on the stick quickly to rotate the pitch attitude to zero; if the rate of descent was not arrested, the effect would be only marginally beneficial.

Aircraft abandonment in the low-level airshow environment remains an extremely constraining factor on aircrew survival, even in the case of ejection seat equipped aircraft. The demands of low-altitude, high descent rates, unusual attitudes and pilot physiology requires proper pre-planning and the definition of critical areas within the display sequence that jeopardise the survival index of the pilot – such areas must be well understood by the display pilot. As in all things in modern life, everything is getting more scientific with analyses of each possible situation leaving less to chance or the human's poor decision making ability under highly dynamic situations. Because of the extremely high downward velocity vectors during certain display manoeuvres, the decision to ultimately abandon an aircraft or not during a display, must therefore be made on the ground, prior to take-off – the decision to commit to ejection if anything goes wrong is pre-planned – it is not something that is made 'on the fly' (no pun intended).

Referring back to the case of the F-86s, ejection was not an option since civilian owned military aircraft in the USA were required by Federal legislation to have the pilot ejection system eliminated or permanently disabled. This issue was not even open to debate. Not only were ejection seats strictly forbidden by the FAA in civilian operated former military jets, but any armour plating had to be removed and fuel drop-tanks also had to be removed or permanently welded on before civilians could own and operate former military jets. In any case, the F-86 ejection seat is a good example of the earlier, first generation ejection seats that were designed to do little more than keep the pilot in place in the aircraft and fling him out and as such were of little value below 1,000 feet above ground level.

One of the reasons for such a decision by the FAA revolves around the pyrotechnic cartridges used to eject the seat or jettison the fuel drop-tanks. The cartridges and the seats themselves are lethal in the 'untrained' hand. Numerous people, including technicians and pilots, have been killed in the past by inadvertent ejection seat firing. Even within the military environment, the maintenance and use of ejection equipment is rigidly controlled and regulated for use by trained personnel only and the handling of an ejection seat must be by a competent, qualified person having undergone a recognised training course, whether as a technician or as a pilot. In fact, the military regards the ejection seat as hazardous equipment to such an extent that pilot must be 'signed-out' on every single different category or mark of seat that they operate before the pilot may fly the aircraft as pilot-in-command. The ejection seat is treated with the same circumspection and criticality as that of the aircraft - it is a two-edged sword, it can save a life, but it can also take a life if incorrectly used.

At the Classic Jets Convention in Seattle in 1993, the FAA announced that the restriction imposed on 'hot ejection seats' in vintage jets, would be rescinded. The FAA now allows 'hot seats' to be active on ex-military jets provided that the pilot has undergone a 'proper' training course on how to deal with the ejection seat, and provided that the cartridges in the seat are maintained and kept current. This is, of course, within the bureaucratic legislation processes, always subject to change again. The dangers are that the next time a 'civvie jet-jock' punches out of a vintage jet and lives while the aircraft crashes into a schoolhouse, it's possible that all ex-military jets will be restricted again. No current ejection seat design on earth could have saved the F-86 pilots, maybe the Russian Zvezda ejection seat, often sarcastically referred to as a 'lawn dart', may have had an outside chance, but it is unlikely. Nose down, fast and at low altitude, the pilots would most likely have been better off taking their chances with the aircraft.

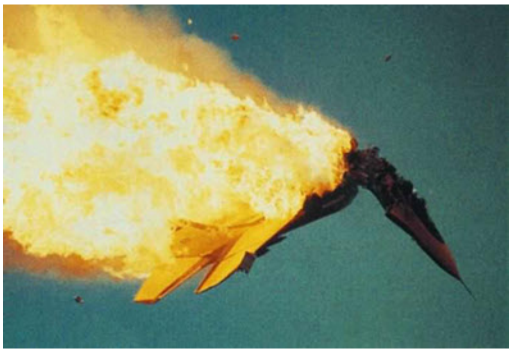
Considering a zero-zero seat similar to those currently fitted to frontline fighters the world over, the escape system is theoretically capable of ejection at zero airspeed and zero altitude. It must, however, be borne in mind that a combination of low airspeed and high rate of descent at low altitude can present a situation more severe than what even a zero-zero seat can handle.

As an example, consider that in a shallow 15º dive at only 200 knots airspeed, an aircraft descends at approximately 5,200 feet per minute - that's a lot of energy for an ejection seat to counter. Charts provided with the F-14 manual indicate that for safe ejection in that situation, 240 feet is required at the time that ejection is initiated, but that doesn't include pilot reaction time. Add two seconds for the pilot's reaction time, a typical time for the decision making process, the aircraft will lose an additional 173 feet. Therefore, with a modern ejection seat in a 15º dive at 200 kts, the pilot would typically, in theory, have had to initiate ejection at some 413 feet above ground level to survive the ejection.

Moments after the collision, Tresvyatsky's aircraft "buckles" behind the cockpit and then explodes. Beschastnov's aircraft is seen pulling up and away with fuel spraying from the severed wingtip. (Aviation Week & Space Technology)

And now the cruel irony of the situation. An F-86 and many vintage jets don't have a modern zero-zero ejection seat. In this case, the pilot would have needed even more altitude, BUT at that higher altitude, he may have held out the hope that he could have completed the recovery pull-out. And herein lies the crux of the matter; the ability of the pilot to decide whether or not the aircraft is on the correct 'energy path' to ensure recovery. Add to this the fact that it is extremely difficult for a pilot to make the decision to eject from a perfectly serviceable aircraft and the result is inevitably catastrophic.

Just how much to allow before deciding to 'stay' or 'go' is the one aspect for which a pilot cannot practice and that is why it is essential for the use of 'energy gates' in the display routine. The 'energy gates' are there to assist the pilot in the decision making process since the human's decision making capability is not sufficiently refined to enable such decisions to be made accurately and consistently. A contribution to the problem stems from the fact that accurate depth perception is not well developed in the human and the medium of air is invisible, there is no tangible method or fixed reference point to determine distance and closure rates accurately to assist the pilot in anticipation and decision making.



Tresvyatsky's aircraft engulfed in flames (Aviation Week & Space Technology)

The importance of 'energy gates' cannot be overemphasised - this is not a 'seat of the pants' thing; if the aircraft potential energy values of airspeed and height are not correct to within a very small 'scatter band', then a decision must be made. A GO/NO-GO decision, it is not a negotiable issue, it is a black or white issue – a decision must be made. If the pilot is outside the 'gate' at any point in the particular sequence, the 'gate' must not be forced open, but an 'out' manoeuvre should be available to the pilot to exit safely from the manoeuvre. The 'key' to open the 'gate,' is the correct airspeed, height and aircraft attitude.

The blazing aircraft plummeting towards the ground. Tresvyatsky ejected while the aircraft was still erect, and the seat stabilizers have deployed. (Aviation Week & Space Technology)

Ejecting from an aircraft that is out of control or has a fire, engine or structural failure, or any similar catastrophic failure, requires a GO/NO-GO decision and in such cases, for the pilot, the decision is relatively easy to make. The decision has been drilled in during training and pre-flight briefing. The more difficult decision to make is the one to eject from a perfectly serviceable aircraft in which the pilot is of the opinion that he might just be able to 'save the situation'. This is the very reason that pilots have been killed for many years, their inability to make the decision timeously by not recognising that the odds are stacked against saving the situation has been the highest causal factor contributing to low-level ejection fatalities. The fact of the matter is that low-level aerobatics are inherently hazardous and there is very little margin for error or failure, mechanical or structural. No manner of fancy gizmos, procedures or hi-tech widgets can make it completely safe.

The survival enhancing features of the ejection seat were already in evidence on 17 May 1980 when the *Red Arrows* lost the first Hawk during a display over the Brighton sea front. On the fourth opposition pass, Synchro-2 struck the mast of a yacht which, unnoticed, had motored slowly on to the previously clear display line. The yacht carried no sail at the time and the pilot, Sqn Ldr Johnson, with the aircraft out of control and almost inverted and at no more than 300 feet above sea-level, ejected just three seconds after the collision.

RIAT '93 spectators at RAF Fairford and the general public watching on television in the comfort of their armchairs, stared in awe as the two civilian Russian test pilots, Sergey Tresvyatsky and Alexander Beschastnov amazingly escaped with only minor injuries following ejections at extreme low-level from their Mikoyan MiG-29 fighters. The two MiGs from the Russian Flight Research Institute at Zhukovsky (Moscow) collided during synchronised-pairs aerobatics as Tresvyatsky was pulling out of the loop and Beschastnov's aircraft pulled up across his path. As a result of the collision, Tresvyatsky's aircraft was sliced nearly in half just aft of the cockpit and exploded into a fireball just before he ejected. The blazing aircraft crashed to the ground across from the runway, a short distance from the crowds, impacting behind the flight display aircraft parking area.

Immediately following the collision, Beschastnov also ejected as his aircraft lost control when a section of its left wing was clipped-off. What remained of his wing was ablaze as the aircraft plunged to the ground, crashing into a field about a mile northeast of the base. A spectator commented that "most people around had no idea what had happened to the other MiG since everybody followed the fireball, and then we saw the other parachute."

More amazing however, was the speed at which the pilots managed to eject! It seemed very fast even on video slow motion replay, virtually simultaneously with impact. Was it instinct, do all pilots instinctively know when to eject or did the pilots realise that an accident was imminent? If the pilot was concentrating on flying the MiG and performing all the set moves, it must have been quick reflex since he went for the ejection lever as soon as things went wrong. Such quick response can only be attributed to experience and situational awareness resulting from training and many hours of low-level display flying.

Media headlines such as 'The Great Escape' or 'Russians Cheat Death' aptly describe the ejection at 100 to 200 ft overhead the runway at Le Bourget. (Aviation Week & Space Technology)

In surely one of the most spectacular airshow crashes, the twin-seat Sukhoi Su-30 MK prototype crashed at the 1996 Paris Airshow while attempting to pull out of a descent that included three high 'alpha' downline rolls using vectored thrust. Using their Zvezda K-36 ejection seats, the navigator ejected first at a height of around 100ft (30m), followed by the pilot at some 200ft (60m) - both landed safely and walked away from the crash. If the mishap brought frowns to Sukhoi, it brought smiles to Zvezda, whose K-36D ejection seats functioned to perfection. Noting that the same seat had saved the life of Anatoly Kvotchur when a MiG-29 crashed at the Paris airshow ten years earlier, chief designer Gay Severin called attention to the fact that the two seats had ejected almost simultaneously but in *different trajectories, so that they would not collide in mid-air. It was miraculous that both pilots survived with no major injuries - the occasional reference to the "Russian Low Altitude Ejection Team" has its origins in this accident.*

During this particular Paris Airshow, Zvezda displayed the latest version of the seat, the K-36D Model 3.5 that was 25 kg. (55 lb) lighter and smaller than any other current model and was additionally provided with an ergonomic design capable of accommodating lighter mass, women pilots. The new seat was equipped with a computer processor that recorded the dynamic parameters at ejection, automatically selecting optimum ejection impulse conditions to suit the pilot's weight. Severin said the existing seat allowed pilots to return to active duty at a rate of 97%, higher than any other competing ejection seat.

However, Martin-Baker officials quickly countered this claim stating that this was the same rate achieved by their current generation of ejection seats. The UK Company supplied ejection seats for Eurofighter and Rafale and were selected as a member of Boeing's Joint Strike Fighter team. The superb performance of the Russian seat led to the USAF also evaluating the Zvezda K-36D seat in a foreign comparative test programme.

No discussion on aircraft egress would be complete without considering what happened in the Jet Provost incident? An avid aviation enthusiast and pilot bought one from the RAF and took his brother for a flight. He started to demonstrate some basic aerobatics and as the aircraft went inverted, the last sight he had of his brother were his boots going out a hole in the canopy. He made an emergency landing believing his brother had jut died, but fortunately however his brother had paid attention to the safety briefing before the flight and had managed to separate from the seat and open his parachute. Apparently when the RAF had disabled the ejection seat and replaced it in the aircraft it hadn't been fastened in properly hence it had fallen straight through the canopy when the pilot rolled the aircraft.

For the display pilot flying an ejection seat equipped aircraft, the decision to eject is available and provides the pilot with an option for survival provided the decision-making capability is not handicapped. But in an aircraft without an ejection seat and below the minimum bailout height, the pilot is forced to remain with the aircraft. The amount of control and steering options available to the pilot obviously being a function of the aircraft's residual total energy and a measure of the pilot's survival probability.

MANUAL BAILOUT

The case of the Rouen Valley Spitfire crash portrays the worst-case example of a pilot at low-level without the option of abandoning the aircraft and even less energy to manoeuvre. The result in this case was loss of control followed by departure and spin. At the time of the crash there was general reporting in the UK to the effect that, following power failure of the engine, Martin Sargeant had initially attempted to land on the grass runway designated for emergency use but had been unable to do so due to spectators having spilled onto this area. In an attempt to realign the aircraft onto the active runway, he lost control and crashed, the Spitfire being destroyed and Sargeant losing his life.

Many aircraft on the airshow circuit, both the vintage warbirds and the aerobatic category aircraft, are not usually fitted with ejection seats - so what emergency egress and abandoning options are available to the pilot? Obviously, in most cases during a low-level aerobatic sequence, a manual bailout is virtually impossible unless near perfect conditions of attitude, altitude and time permit. Even though the display pilots would in most cases be too low for safe bailout, the question of manually bailing-out from an aircraft, remains contentious.

Rick Stowell (Master Instructor - USA) conducted a study into the subject of manual bailouts realising that the FAA/IAC requirement to wear parachutes during aerobatics is moot. This seems to be borne out by a sentiment expressed by an experienced airshow aerobatics competition and display pilot: "If things get that bad, we won't have time or altitude to use that overpriced lump of fabric anyway!" The mindset represented by the last statement has always been contentious for two reasons. Firstly, there are many pilots who have successfully bailed out in emergency situations, but, were they just lucky? Secondly, others have been donning a parachute regularly during their entire careers spanning many years yet have never had to jump out of an aircraft. That said, the next question is: “would most pilots actually be able to take the plunge if necessary”?

To address the questions, Stowell performed searches of the NTSB on-line database for the keywords “parachute,” “chute,” and “bail” for the range of years available (1983 onwards). He disqualified accidents involving skydiving operations, aircraft equipped with ballistic recovery systems, high performance military aircraft (other than two T-6’s and two T-28’s), and accidents in which it was unclear from the narrative whether or not those on board were wearing parachutes.

Seventy-nine aircraft accidents remained involving an ultralight, a homebuilt amphibian, gliders, factory and experimental aircraft, aerobatic and non-aerobatic aircraft which involved a total of ninety-six people. Sixty-two of the accidents had only the pilot on board while the remaining seventeen had a pilot and a passenger on-board. The broad causes for the accidents are tabulated.

Manual Bailout Accident Causal Factors.

Mechanical Problems (32)			Loss of Control (26)		Other Causes (21)			
Control Failures	Structural Failures	Flutter	Spins	Other	Fire, Fuel, Engine	Low-Level Aerobatics	Mid-air	Other
18	11	3	15	11	6	5	4	6

For those who did not bailout, the synopses revealed twenty-one fatal accidents in which it appears that no attempts were made to bailout. No one onboard these aircraft survived, resulting in thirty-three fatalities in all. Five accidents, four of which had two people on board at the time, involved ill-advised attempts at low-level aerobatics raising the question of what’s the point of complying with ‘FAR 91.307-Parachutes’ and then disregarding ‘FAR 91.303-Aerobatic Flight’? Two other cases may have involved pilot incapacitation; physical impairment was listed as the cause of one accident and in the other, the pilot may have been incapacitated when the wing separated from the aircraft.

The synopses also revealed two non-fatal accidents where no bailout was attempted, ‘unusual’ cases, to say the least. In one, the parachute itself seems to have contributed to the accident, the pilot was testing out a ‘new’ parachute in his aircraft. The chute, however, positioned the pilot several inches closer than normal to the rudder pedals and restricted full movement of the stick resulting in the pilot loosing directional control during landing and receiving minor injuries. The second accident involved a non-recoverable deep stall in a Velocity (this incredible story was recounted in *Sport Aviation* magazine). The test pilot actually started to loosen the seat restrain straps but noticing the development of a slow, wings-level descent and the lack of forward speed, re-strapped himself into the seat and descended with the aircraft into the water, escaping uninjured!

For those who bailed out, fifty accidents involving fifty-two people were recorded in which all on-board managed to bailout. Included were two accidents, each with two people on board, wherein both pairs bailed out and survived; one person sustained serious injuries, one person minor injuries, and two people, no injuries. The tabulated breakdown of injuries sustained by all those involved in these bailout accidents is listed.

Manual Bailout Injuries

	Number	Percentage
Fatal	9	17
Serious	9	17
Minor	18	35
None	16	31

83% of those who bailed out survived of which 66% experienced minor or no injuries while 17% received serious injuries although the extent of the serious injuries was not listed in the accident synopses. What about the remaining 17% who bailed out but didn’t survive? Four of the nine fatalities appear to have been emergency egresses at altitudes too low for parachute deployment. The narratives used phrases such as "bailed out too low," "chute did not open," and "chute did not fully deploy." One of these involved a flat spin entered between 7,000 and 8,000 feet above mean sea-level (AMSL); the pilot, however, stayed in the aircraft until an estimated height of 500-600 feet agl before attempting to egress. As in the case of the ejection seat aircraft, an early decision to bailout is essential, any delay reduces the probability of survival.

Although not directly related to airshow display flying as such, one tragic case involved a pilot returning home from a contest when for undetermined reasons, he had to bailout of the aircraft. Since it was a cross-country flight, the pilot was apparently sitting on, but not securely fastened into his parachute. Upon deployment, the pilot and parachute separated. Another fatality occurred when the pilot's parachute apparently deployed too soon during the egress process, becoming entangled inside the aircraft and another fatality occurred when the parachute itself suffered structural failure.

Those who escaped with their lives did so from a range of estimated bailout altitudes from as low as 300 feet to as high as 6,500 feet. They exited from a variety of aircraft, Rebel 300, Beech A36, Cessna 150 and P210, Bellanca 7 and 8KCAB's, Pitts S-1 and S-2B, One Design, Su-29, Aeronca 7BCM, Cap 10B, DG-400 and Concept 70 motor-gliders, T-28, Slingsby Dart and Vega gliders, Goshawk 350, Cassutt and a Velox Revolution II.

Of the bailout survivors, 56% exercised the option to use their parachutes as a result of some sort of mechanical problem with their aircraft (elevator, aileron, or rudder control problems, structural failures and flutter). 25% successfully used their parachutes following the loss of control of the aircraft (spins, severe turbulence, etc.), 13% exercised the bailout option as a result of fire, fuel, or engine problems and 6% bailed out after a mid-air collision.

So, on the statistical evidence presented by Stowell, the first question can be answered, namely, that bailing out is confirmed as a viable, survivable, often preferable option in an emergency – but would one actually be able to jump if the situation warranted it and there was sufficient height available? Do display pilots have the necessary committed mindset or state of mind to make the decision? Of course all aircrew are briefed on egress procedures. They've read the 'how to' articles and attended the forums on emergency bailouts and they've collected literature from parachute manufacturers. Sure, they've strapped on a chute, pulled the ripcord and then watched as the rigger repacked it.

During a low-level aerobatic display sequence, although the height above ground level may be low, in certain circumstances where the potential energy of the aircraft is sufficiently high, it may be possible to zoom the aircraft to an altitude high enough to enable bailout. Invariably though, experience has shown that provided the aircraft is still under control, pilots generally elect to remain with the aircraft and take their chances with a crash landing unless forced to bail by a catastrophic failure or fire. On 25 February 2002, Brazilian aerobatic pilot, Paulo Henrique, successfully bailed out of his Extra 230 when, during a practice session, he noticed a vibration on the stick, ultimately ending in a total loss of the left aileron. Not being able to gain control of the aircraft which was in a dive, he made a quick and smart decision to bail out at 1,000 ft agl and landed safely without injury.

Although the aforementioned statistics do not deal specifically with airshow accidents but rather general aviation manual bailouts, they do indicate that survival from manual bailout is only feasible provided adequate height is available and that the pilot is not incapacitated. Considering the lack of skill, experience and practice in manual bailout by the average pilot and compared with the relatively low kinetic energy of crash landing the aircraft under control, the probability of surviving the crash, appears to be considered by some pilots as acceptable, but this obviously also requires a fair amount of luck.

Once again consider for instance the Spitfire crash at the Rouen Valley 2001 airshow. The pilot tried to reposition the aircraft for an emergency landing to avoid spectators but the aircraft departed at very low-level and the pilot, Martin Sargeant, died in the post-crash fireball. On the other hand, the crash of the South African Air Force Museum Spitfire at AFB Swartkops in 2000 was survivable. Lt Col Neill Thomas elected to stay with the aircraft and do a forced landing rather than bailout and even though the aircraft crashed in the 'veld' and also crashed through a concrete wall, the pilot walked away from the crash suffering only minor cuts and bruises. Lucky or what?

One very important point that must be emphasised in this comparison is that in the first case of the Rouen Valley Spitfire, the aircraft was out of control while in the second, the SAAF Museum Spitfire, the pilot was able to control the aircraft to a certain extent which effectively reduced the impact energy levels; a 'controlled crash'. Pilots, it would seem, are not overly keen to bailout of an aircraft manually unless catastrophic failure, uncontrolled flight or fire leaves them with no other option, a 'last-ditch' manoeuvre only.

In theory, ejection is the much easier decision to make, the process of simply pulling a handle to activate the automatic ejection sequencing from the aircraft, including automatic seat separation, stabilisation and chute deployment is a low-workload case. The odds of successfully bailing out of an aircraft manually in an emergency are, however, surprisingly good, especially when compared to the statistics in which the pilot elected to remain with the aircraft or the bailout was attempted too late. It's also likely that a number of the fatal bailouts themselves would have been survivable had the pilot's exercised better judgment before or as the accidents unfolded.

DEPARTURES/SPINNING

Although the spin is recognised as an aerobatic manoeuvre, spins are not really in the same class as other conventional aerobatic manoeuvres and should be regarded differently. The spin is one of the few dynamic manoeuvres occurring about all three axes simultaneously and coupled to a relatively high descent rate, it thus deserves particular respect because the aircraft departs controlled flight at low altitude and relatively low energy which implies higher risk in effecting recovery. In principle, there is also no objection to planned spinning demonstrations by aircraft at airshows provided that the aircraft is cleared for such manoeuvres and that the entry altitude provides adequate height for recovery. Sounds simple enough, but display pilots still get it wrong occasionally.

Even today, spinning is still held in awe by the general public, some aviation enthusiasts and pilots alike. Intentional spins in an airshow routine certainly grabs the attention of the spectators due to the dynamic nature of the aircraft trajectory and the aura associated with spinning accidents in world aviation history. Including a spin in the airshow routine not only demonstrates the controllability and recovery characteristics of an aircraft, but also the skills of a pilot in first taking an aircraft out of controlled flight, into uncontrolled flight and back into controlled flight again. There is also a degree of peer respect by pilots for pilots prepared to demonstrate low-level spins recognising a 'touch of courage' - of having the 'guts' to handle an aircraft in uncontrolled flight at high descent rates and low altitudes where there is zero error margin.

In the interests of display safety, it must be emphasised again that the first energy boundary of the display aircraft is the stall boundary and the display pilot must abort any manoeuvre at the first indication of the stall by unloading the aircraft, achieving stabilised flight and accelerating out of the 'high alpha' regime – that is the first priority. It must be done immediately, it is time to put away pride, reconfigure and set-up again, but only once sufficient energy has been regained. The crash of the Kingcobra at Biggin Hill in 2001 illustrates the folly of transgressing the first boundary by entering an incipient spin, recovering and then continuing the show with ever decreasing energy levels - a crash waiting for a place to happen!

When the spin goes wrong, as with all other low-level manoeuvres, well, the probability of safe recovery is extremely low. South African aerobatic champion Nick Turvey, in front of a crowd of several thousand spectators at the Africa Aerospace Airshow in 1981, was attempting a record thirteen turns of the inverted spin. The commentator counted out over the public address system as each turn of the inverted spin was completed and although the aircraft recovered from the spin, there was inadequate height to affect a safe recovery pullout and the aircraft impacted the ground. Miraculously the aircraft did not explode on impact but Nick Turvey was hospitalised for several months.

Within the sample of airshow accidents considered, a total of twenty-four (20%) were attributable to Loss-of-Control accidents. The relatively high percentage of accidents of this type also highlights the requirement for above average handling skills required by the display pilot, especially critical in the realm of low-level aerobatics flying. Although skills level is an important consideration, pilot judgement is equally important. The wisdom to overcome personal ego, the ability to hold back from trying to be more spectacular than the previous display or the competition, the ability to recognise diminishing energy levels and 'break it off' via an exit manoeuvre and the discipline to remain within the planned routine, are all aspects that require good judgement from the display pilot. Failure to exercise good judgement in the low-level display arena can only add to the already unacceptable statistics of loss-of-control.

The classic loss-of-control accident spectrum spans the entire range of aircraft categories, from ultra-light to modern front-line fighter. At the bottom end of the range, the Starlight Warp Ultralight at Sun-'n-Fun (USA 1998), the vintage aircraft include the Wirraway in Nowra (Australia 1999), the De Havilland Mosquito (Barton, UK, 1996), the Kingcobra at Biggin Hill (UK) in 2001, the Hawker Sea Fury at Sarnia (Canada 2001) and the vintage Harvard at New Mexico (USA 2001) all contributed to loss-of-control airshow accident statistics. There was even an Airtractor crop sprayer (Australia 1998) and the top of the range aerobatic category aircraft such as the Royal Jordanian Air Force Extra 300 (Belgium 1997), which fell prey to pilot mishandling. Moving to the top end of the range, frontline fighters such as the Su-27 (Ukraine 2002) and the F-14 at Willow Grove (USA 2000), also all contributed to the airshow accident statistics.

Next to actually flying the aircraft into the ground due to pilot judgement error, the most disastrous mistake the display pilot can make is to lose control of the aircraft, departing controlled flight into ground. It is surely also the most basic mistake a display pilot can make and as in all cases in aviation, the end result can only be catastrophic at the low heights associated with display flying.

The stall is a minimum energy state for a fixed wing aircraft that can lead to departure from controlled flight along the shortest direct path to the ground. In the sample of airshow accidents, at least eleven of the loss-of-control accidents were categorised as stall/departure/spin accidents, accidents in which pilots allowed the energy to bleed into the high alpha regime at very low heights. This does not include the Ukrainian Su-27 (2002) crash, which was essentially an accelerated, hence high-speed, stall case. Most disconcerting was the fact that these pilots were highly experienced and should have recognised that the critical boundary separating controlled and uncontrolled flight had been breached – yet, they allowed the reducing energy state to continue instead of aborting the routine and exiting to allow the energy to build-up before either continuing, or abandoning the sequence.

It is possible to describe a spin as a sort of third order failure, regressing from a stall, through the departure phase and then into the spin. It must be re-emphasised that the display pilot cannot afford to reach any one of the three phases, especially at low-level. There is no second chance as the pilot of the vintage Mosquito discovered in the accident in the UK during 1996; having recovered from the first spin, the aircraft immediately entered another spin in the opposite direction from which insufficient height was available to recover. The findings of the Accident Investigation Board concluded that the aircraft entered a left-hand spin from a wingover at approximately 1,000 ft agl from which it appeared to recover briefly before entering a spin to the right. Shortly before impact the aircraft appeared to recover from the spin in a steep nose down attitude from which it had insufficient height to recover.

The major recovery problem for any pilot inadvertently entering a spin at low-level, is to move the control column sufficiently forward to unstall the aircraft – it goes against the very instinct of the pilot to push the stick forward with the nose already pitched-down in an erect spin and the ground approaching very rapidly. Pilots will have no problem kicking opposite, anti-spin rudder, but getting the stick sufficiently forward, is psychologically, a difficult task. The recovery trajectory of the Barton Mosquito crash, most probably represented just that. What appeared to be an initial recovery from the spin was in fact more than likely just the crossing-over from one side to the other, without actually recovering from the spin.

In an effort to understand the geometry of this particular spin accident, and in view of the unavailability of quantitative data on the Mosquito spin recovery characteristics, it is intuitive to consider the spin of a similar vintage aircraft. The vintage warbirds spin behaviour can also be understood by considering the spin recovery characteristics of the Spitfire. During WWII, spinning trials were randomly carried out to check the behaviour of the aircraft coming off the production line. Remarks in the flight test reports of that period typically describe the spin recovery characteristics as "following two free turns, spins to the left were smoother than those to the right, though the recovery was slightly quicker from the right". This was common to all Spitfires.

"Spin recovery was made by applying full opposite rudder and easing the control column forward to just aft of central, but in cases where full opposite rudder was applied and the control column held back, the aircraft stopped spinning after two turns, but immediately entered a spin in the opposite direction. This could be prevented by violent use of the rudder but it was necessary to ease the control column forward to gain sufficient speed to unstall the aeroplane". The aircraft usually recovered within 1½ turns but the height required for recovery after two free turns was typically 3,800 feet and if the stick was held back for one additional turn in the opposite direction, the height required was approximately 8,000 feet. The bottom line is this – when the Barton Mosquito entered an inadvertent spin at approximately 1,000 feet agl, there was really no other result possible – irrespective of pilot skill the physics of the recovery, returning the aircraft to controlled flight, required a given height band which was greater than 1,000 feet.

This obvious question that comes to mind is: "How much stall/departure/spin training is done by display pilots? The counter argument that immediately follows of course is: "Why practice spin recoveries if the result of a low-level spin is anyway, catastrophic? Surely pilot training for low-level display flying must concentrate on the recognition and avoidance of breaching the lift boundary rather than recovery from stalls, departures and spins. Once the barrier has been breached, it is incumbent on the pilot to unload the aircraft and ensure that positive acceleration occurs and that no asymmetric yawing moments are generated. Such asymmetric yawing moments would typically be induced by the incorrect use of rudder or aileron, which could generate rotation about the normal axis and produce the sideslip necessary to induce autorotation. Once the autorotation commences at low altitude, the probability of recovering is not high.

Unfortunately, due to the complex energy states of an aircraft during a spin, coupled to the pilot's unpredictable response to a low-altitude departure, it is difficult to predict with any consistency, the exact height required for recovery. It is however, possible to determine the height lost for a well-practiced display pilot anticipating a departure or spin. Unfortunately, in the real world of display flying, a departure or spin is usually an unexpected occurrence and as such catches the pilot off guard and it is this response of the pilot that is unpredictable. The time available to the pilot to recover is a function of aircraft height, configuration, power setting, airspeed and pitch attitude at the time of departure. Then there is the inconsistent aircraft response, a function of the pilot's recovery control input; are the controls correctly applied, what is the effect of slight aileron into or out of spin? What is the effect of less than full opposite rudder? What is the difference in recovery between left and right hand turn spins? What about the patience of the pilot in waiting for spin recovery with the ground rushing up at what appear to the pilot to be an amazing rate.

In a low-altitude inadvertent spin, there is no pilot that will have the necessary patience to 'wait and see' if the anti-spin control inputs are working, the end result is invariably a number of rapid permutations of anti-spin control inputs being made by the pilot under extreme duress. With everything happening so quickly, the pilot does not have, or allow enough time, to enable the aerodynamic moments to build up to a level to counter the inertial moments and the probability of a successful recovery verges on the miraculous.

Aerodynamically, what makes spin characteristics for an aircraft unpredictable, is the separated airflow - part of the problem of high angle of attack and departures arises from the aerodynamic non-linearities arising from flow separation and vortex formation. The possibility of 'cliff-edge' effects also exists where a series of changes may have no effect up to a certain point but beyond which, even a slight change may have drastic consequences.

The autorotational property of a wing at post-stall incidence is the primary cause of spinning but this does not necessarily result in a spin. The damping moments provided by the fuselage and the fin oppose the propelling moments from the wings, with the result that for a given combination of control positions, there is a single value of equilibrium rate of rotation at each angle of attack. A spin can, however, only occur if equilibrium of aerodynamic and inertial pitching moments can be sustained. This is true for all aircraft, irrespective of inertial distribution. If equilibrium of pitching moments and rotary moments cannot be obtained simultaneously, an oscillatory spin or self-recovery will occur.

Without getting too technical, if the inner wing is tilted down, sideslip towards the inner wing produces an anti-spin damping moment due to dihedral effect. There is also a component of nose-up pitch rate that combines with roll to generate an inertial yawing moment. Whether this is a propelling or a damping moment, depends on whether the moment of inertia in roll (A) is greater than in pitch (B) or vice versa. This can only be understood by isolating the motion in roll and pitch. The effect of wing tilt is addressed in Table 2.

	Mass in fuselage Dominant A<B	Mass in Wings Dominant A>B
Inner Wing Down	Damping	Propelling
Outer Wing Down	Propelling	Damping

Table 2. Effect of wing tilt angle on spin *motion.*

Aircraft with the mass spread mainly along the wings tend to spin more readily, requiring only a small amount of in-spin, wing tilt. They are generally more difficult to recover because out-spin rudder increases the in-spin wing tilt (nose-up pitch rate) and the resulting inertial yawing moment opposes the direct effect of the rudder. It is therefore more important to apply down elevator to resist the nose-up pitch rate and assist recovery on such aircraft.

Aircraft with mass spread mainly along the fuselage, tend to be easier to recover. Modern combat aircraft however, with high structural density, have very high rotational energy, even at quite slow rates, so the controls take a longer time to have effect. Add to this the higher rates of descent due to high wing loading, the height loss on recovery can consequently be significantly greater, even from a docile spin. Aircraft can be unspinnable if the rotary damping is excessive or the nose-down pitching moment at high incidence is large enough, but it is very rare to find an aircraft that will not spin with some combination of control positions, even though it may not respond to the conventional entry technique. It is essential for the display pilot to know the spin susceptibility of the particular aircraft being flown since the degree of susceptibility will dictate the maximum angle of attack (minimum airspeed) for any and each of the sequence's manoeuvres.

Spinning is a complicated and long-winded subject in which it is hard to generalise without saying too much or too little. The interaction of aerodynamic properties such as size, mass disposition and relative proportions of the aerodynamic surfaces basically determine the characteristics of a spin. As an aircraft approaches the stall, the aerodynamic changes produced by flow breakdown over the wing and tail result in degraded stability and control effectiveness. It is the extent of this degradation which determines whether the aircraft is departure prone or departure resistant. The use of flight controls to prevent departure may not be effective because both aileron and rudder effectiveness are greatly reduced in the high angle of attack regime and, in addition, adverse yaw characteristics may prohibit the use of the aileron during stall recovery. In many aircraft, the manufacturer's published stall recovery stipulates picking the wing up at the stall with rudder – it is such aircraft in which adverse yawing moments may be produced by aileron application which can drive the departure.

If the aircraft becomes directionally unstable but still retains a stable dihedral effect of sufficient magnitude, this departure will not be divergent. When both directional stability and dihedral effect become unstable, then any disturbance such as a gust, slipstream or control input, can result in a departure. The departure may be self-terminating or it may result in subsequent spin entry. The important question is that once a departure has occurred, is there any restoring tendency that will impede further uncontrolled excursion and if so, how is it manifested?

A flying display had been organised by the flying club at White Waltham (UK) under CAVOK meteorological conditions with a surface wind of 320°/10-15 kts. One of the early items on the display programme was a formation display by three Tiger Moths and a DH Rapide which was planned to culminate with two Tiger Moths flying at right angles towards the display line before breaking to the left and right respectively to fly away parallel to the display line in opposite directions.

The two aircraft flew towards the display line at a speed of approximately 70 kts and commenced their 'break'. The aircraft breaking left did so without difficulty. Video evidence showed, however, that the aircraft breaking to the right entered the turn with a high rate of roll, as if a full lateral control input had been applied, although it was not possible to see the position of the ailerons on the video. What could be seen however, was the application of a substantial amount of right rudder coincident with the start of the turn. As a result, the nose of the aircraft dropped after it had turned through approximately 80° and this was countered by the application of nose up elevator. Substantial right rudder and nose-up elevator remained applied causing the aircraft to enter a spin to the right. The rudder was then centralised and the aircraft completed one further turn before striking the ground.

After impact, the pilot, who had been occupying the rear cockpit, released his harness but was unable to free his legs which had become trapped by elements of the distorted structure. An Air Ambulance helicopter was on scene within two minutes of the accident and the pilot was later flown to a local hospital. The front cockpit of the aircraft had been completely destroyed in the impact and the pilot received severe back injuries.

Prior to the formation display, the pilot had flown a Zlin and had performed a number of aerobatics. The Zlin requires robust control inputs during aerobatics whereas the Tiger Moth, with its weak lateral and directional stability, requires relatively light control forces. It is possible that the pilot had utilised techniques required to fly the Zlin during his first aggressive manoeuvre on the subsequent flight in the Tiger Moth. (AAIB Bulletin No: 11/2002Ref: EW/G2002/07/23)

If the aircraft pitches nose-down at the stall, or if the longitudinal control retains full effectiveness, the departure may be terminated through the reduction in angle of attack. There may even be a restoring tendency at large angles of attack where the vertical tail emerges from the wing-body interference field to restore both directional stability and dihedral effect sufficiently to attenuate the departure tendency – an aerodynamic phenomenon found on some aircraft capable of generating high angle of attack, especially at aft CG positions.

As an example of some of the idiosyncrasies of the spin's cross-coupling dynamics, on some aircraft, there can be cross-coupled effects. Working against a self-reducing angle of attack, can be a strong nose-up pitching moment at the stall, which is actually due to sideslip – a mechanism manifested in the Northrop F-5 at extreme aft CG and commonly referred to as sideslip/angle of attack coupling. It can be insidious because the pilot usually does not perceive the increase in angle of attack and consequently does not relax stick pressure before excessive pitch angles are attained. When increases in angle of attack and sideslip both result in further degradations in directional stability and dihedral effect, and longitudinal control is not effective or is not applied, departure and subsequent spin entry are highly probable.

Aircraft spinning characteristics are an important area of design for recreation aircraft, general aviation aircraft and military fighter and trainer aircraft. An effective aerobatic aircraft must obviously be designed to be sufficiently free of adverse flying qualities so that the pilot can focus attention on flying the manoeuvres. This is particularly critical in the high angle of attack region where the pilot may be concentrating on positioning the aircraft to remain within the competition box or the showline in the display arena. However, in non-competition aerobatic, homebuilt experimental aircraft or even some military aircraft designs, some nasty spin characteristics may exist and it is prudent for the display pilot to be aware of such characteristics obviously ensuring that no segment of the show routine will lead to possible entry into such a regime.

Taking a slightly more technical review of this interesting subject, and without going to deeply into the theory, it is necessary to briefly consider some of the essential dynamics of the spin. As previously mentioned, the spinning characteristics of the aircraft are essentially a contest between the aerodynamic moments on the one hand, and the inertial moments on the other. In a nutshell, several aerodynamic coefficients, quite logically, determine the susceptibility to departure; it is those coefficients that contribute to rolling and yawing moments and how they are affected by sideslip that are the essential ingredients of the spin. More particularly the yawing moment due to sideslip (C_{n_β}), the yawing moment due to aileron deflection ($C_{n_{\delta a}}$), the rolling moment due to sideslip (C_{l_β}) and the rolling moment due to aileron deflection ($C_{l_{\delta a}}$). Importantly, these coefficients are essentially the rolling and yawing moments due to sideslip and aileron deflection that drive the aerodynamic moments necessary to generate the inertial moments in the spin.

The modern prediction parameter for aircraft spin susceptibility is expressed as the Lateral Control Departure Parameter (LCDP) or $C_{n_{\beta_{dynamic}}}$ which is essentially the difference between the yawing moment due to sideslip C_{n_β} and the rolling moment due to sideslip C_{l_β}. The inertial moments are represented by the yaw inertia I_z and the roll inertia I_x. This equation neatly sums up the importance of aerodynamic versus inertial moments as driven by sideslip and manipulated through angle of attack. In fact, the LCDP focuses upon the relationship between adverse yaw and directional stability.

$$C_{n_{\beta_{dynamic}}} = C_{n_\beta}\cos\alpha - \frac{I_z}{I_x} C_{l_\beta}\sin\alpha$$ where $C_{n_{\beta_{dynamic}}}$ = directional departure parameter per degree

C_{n_β} = directional stability derivative (body axes)

C_{l_β} = dihedral effect derivative (body axes)

$\frac{I_z}{I_x}$ = yaw to roll moment of inertia ratio

α = aircraft angle of attack in degrees

The fact that the stall/spin manoeuvre still causes aircraft accidents, indicates that in spite of extensive research over many years, even in leading aeronautical laboratories, that an economic design solution to the problem of spinning has not yet been found. Although the basic mechanics of the spin manoeuvre are essentially the same for all classes of aircraft, the wide range of aircraft shapes and mass distribution results in a marked variation in both the aerodynamic and inertia forces and consequently in the characteristics of the spin manoeuvre. It is acknowledged that a considerable amount of pilot experience of the aircraft spin manoeuvre exists, particularly concerning spin entry and recovery techniques.

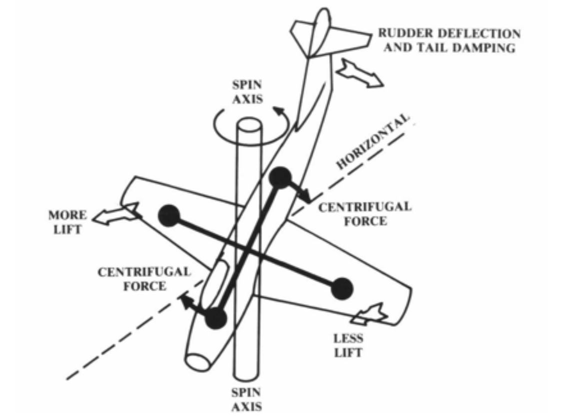
The spin has traditionally been divided into four stages, viz. spin entry, incipient spin, steady spin, and spin recovery. Spin entry from unstalled flight may be deliberate, usually as a training rather than an operational manoeuvre, or inadvertent, usually occurring during low speed manoeuvres.

The deliberate spin is usually initiated by slowing the aircraft to the stall angle and then applying full rudder or a combination of rudder and aileron deflection to promote pro-spin yaw and asymmetric lift generation. An inadvertent spin passes through the same dynamic phases, usually uncommanded but driven through aerodynamics, nevertheless. A large loss of lift due to increased incidence on the inside wing occurs while the incidence on the outside wing is reduced. The resulting differential lift produces a rolling moment in the direction of the inside wing and initiates the spin. Aircraft with high 'spin resistance' generally require vigorous and precise control movements to initiate the spin. In contrast, aircraft with low spin resistance, are more likely to inadvertently enter a spin during the low speed portions of aerobatic manoeuvres such as the hammerhead stall, Immelman or tailslide.

The 'incipient spin' is the transition between 'spin entry' and the 'steady spin' and any recovery from an inadvertent spin is most effectively achieved in this phase. During the incipient spin, the angle-of-attack increases to beyond the stall angle and the aircraft flight path transitions from horizontal to vertical flight while the rotation in yaw increases to match or frequently exceed that in roll. In fact, if the display pilot does not intervene at this stage, the final result will be catastrophic. It is thus important for display pilots to be able to not only recognise the physical attributes of this developing phenomenon, but also 'feel' the aircraft's energy state and then to apply the appropriate recovery action.

Although in the incipient stage of a spin it is meaningful to differentiate between roll and yaw, once the spin has developed, this distinction becomes academic. To a pilot who is not in spinning practice, the whole world seems to be rotating and the axis of rotation is not easily identified. Even to a practiced display pilot, inadvertent spin entry at low-level is equally problematical in determining the axis of rotation. To even talk about pitching motion as opposed to roll and yaw can be misleading because the display pilot tends to derive motion cues from attitude changes and in the spin, the aircraft can change attitude from 'nose high' to 'nose low' through yaw or through pitch and it is dangerous to translate body axis motion into pilot interpretation of spin axis of rotation.

The incipient phase is considered to terminate when the airspeed has become steady and a downward vertical trajectory has been established. For practical purposes, however, the 'steady spin' is considered reasonably well established after two to three turns depending on aircraft shape and inertial distribution. In the 'steady-state' or 'equilibrium' spin, the aircraft describes a steep spiral motion about a vertical axis, in which spin rate, angle-of-attack, sideslip angle and vertical velocity are essentially constant. In many cases the motion does not reach a steady state, but may exhibit an oscillation about the nominal equilibrium point. The steady spin phase is of particular importance since it represents a stable equilibrium flight condition from which recovery may even be impossible on certain aircraft.



The basic forces acting on an aircraft in a spin. (Reprinted from Aircraft Design: A Conceptual Approach, copyright 1999 D. Raymer, All Rights Reserved, Used with author's permission.)

Some aircraft exhibit more than one 'steady spin' condition or mode, in which case, the sequence of control movements applied during the entry and incipient phases will determine which of the modes is achieved. However, the characteristics of the mode depend only on the aircraft aerodynamic and inertia characteristics and on the flight control positions. In the equilibrium case, there is a balance of forces and moments about all axes; the steady spin is the most complex in that the balance occurs in the presence of large angular rotations about the roll and yaw axes.

In theory, the balance of forces in a

'steady spin' is such that drag is equal to the weight and the lift is equal to the centrifugal force. The spin radius is in the order of several meters, the resultant force is almost normal to the wing and acts approximately at the wing semi-chord and while the normal acceleration is relatively low, the exact values are a function of the type and mode of spin. In practice, the actual balance is slightly more complex in that aerodynamic sideforces exist such that the lateral axis is not necessarily horizontal but may be tilted. The amount of tilt is directly related to the spin helix angle and to the angle of sideslip adopted in the spin while the sideslip is determined primarily by the rolling moment characteristics. It is all very well to discuss the theoretical forces and moments in the spin, but, they become of academic importance only if the display pilot should 'lose it' and depart into a spin from low-level since there is very little likelihood of recovery before impacting the ground.

For a conventional design general aviation or aerobatic aircraft, equilibrium of pitching moments is reached when the nose-down aerodynamic moment is equal to the nose-up inertia moments. The aerodynamic contributions are from the wing and the tailplane normal force. The inertia is proportional to the square of the spin-rate and reaches a maximum at 45º angle-of-attack. Movement of the elevator can add an increment to the aerodynamic contribution but normally this is not of sufficient magnitude to unlock the balance of pitching moments.

Of prime importance for roll equilibrium, is the balance of the aerodynamic contributions due to roll rate and to sideslip. The inertia moment may be positive or negative depending on the wing tilt angle - having a zero value for zero tilt. Note that for a significant change in spin-rate, the rolling moments can be balanced by a modest change in sideslip angle and therefore, as with the pitching moment balance, movement of the aileron adds an increment to the rolling moment, the magnitude of which is normally insufficient to unlock the balance of rolling moments.

Considering the contribution of the aileron, elevator and rudder for the display pilot, the two largest aerodynamic yawing moment contributions for a conventional layout, are due to spin-rate and rudder deflection. By comparison, the contribution due to sideslip is small, and, as with the rolling moment, the inertia contribution is zero for zero wing tilt. Since the rudder can alter the yawing moment appreciably, the key to unlocking the balance of moments in a spin therefore, is to generate a large anti-yawing moment with the rudder.

In order to emphasize the major contributions, the wing tilt and hence rolling and yawing inertia contributions are closely related and are determined essentially by the pitching moment. The sideslip is determined by the balance of rolling moments and although all three control surfaces may be effective in changing the balance of moments, and hence spin conditions, the rudder remains the most effective means of unlocking this balance. For aircraft of substantially different inertia loading and layout, this emphasis may, however, change. As an example, spinning a second-generation swept wing fighter, in most cases, requires alternative methods to induce the spin. For instance, spin entry to a left-hand spin is achieved by full stick back, full left rudder and full out-spin aileron. Recovery then required full opposite rudder and the stick moved laterally to give a fraction of in-spin aileron.

In the consideration of spin entry and spin recovery, there are no theoretical or experimental techniques for defining correct control deflections and control sequencing for optimum entry and recovery. These techniques are determined during flight test and may be refined during operational use. This is another very good reason not to spin aircraft that have not been cleared for spinning by the manufacturer.

Spin recovery for most conventional design configurations is achieved primarily by use of full opposite rudder deflection to arrest the yaw rate. The elevator and aileron, if applied correctly, increases the speed of recovery. For certain aircraft their use is essential while in others, they are sufficiently capable of stopping the spin even with full pro-spin rudder deflection maintained. One particularly sensitive consideration during spin recovery of a conventional aircraft is the sequencing of anti-spin rudder movement with forward elevator control to regain controlled flight conditions.

If the elevator control is moved forward too soon, two adverse effects may occur. Firstly, as the aircraft pitches nose-down, the radius of gyration is momentarily reduced and because of the conservation of momentum, leads to an increase in spin rate. Contrary to the novice's opinion, this is always a good sign of impending recovery. Secondly, as elevator control is moved downwards, the effective rudder area may be reduced, resulting in a reduction in the available anti-spin yawing moment. Alternatively, if the elevator control is moved forward too late, the aircraft may enter a spin in the opposite direction. For aircraft with poor spin recovery characteristics, correct pilot technique is critical and the subtle nuances of particular aircraft give rise to much pilot discussion.

Interestingly, the influence of wing position on spin characteristics is significant. The higher dihedral effect of the high wing, plus the absence of any adverse interaction with the tail because of the higher wing wake, leads to some improvement when compared with low wing aircraft. Both of these factors provide increased damping in the spin causing the aircraft to spin more steeply and so enable an easier recovery.

Subtle changes in spin behaviour may occur due to variations in mass distribution with fuel usage or with stores configuration. At high altitude the application of anti-spin controls can be followed by a 'wait and see' period to verify aircraft response to control inputs. Unfortunately, following an inadvertent spin at low-level, the luxury of 'wait and see is not possible and the pilot in most cases only has time to neutralise the controls, hope that the aircraft spin stops quickly, pull through to the nearest horizon and with altitude permitting, recover. Fighting the motion on the other hand by a succession of rapid control inputs will not leave sufficient time for the aerodynamic stability of the aircraft to effect recovery. Unfortunately, at low-level there is really only one way to overcome the hazards imposed by inadvertent spins during display flying - avoid transgressing the lift boundary, its as simple as that.

CONCLUSION

Aerobatic pilots accept and understand the inherent dangers of their occupation. Striving to minimize their risks, professional aerobatic pilots have honed their skills with hundreds of hours actual practice backed up by years of constant practice and through an in-depth understanding of both the physics of flight and the performance characteristics of their specific type of aerobatic aircraft.

There are Rules and there are Laws. The rules are made by men who think that they know how to fly your aircraft better than you do. The Laws of Physics were made by the Great One. You can, and sometimes should, suspend the rules, but you can never suspend the Laws. Already in the 1960s, Neville Duke, world-renowned test and display pilot on Hawker Hunters summed up the situation; "The low-level at which aerobatics are carried out leaves zero margin for error and hours should be occupied with practice perfecting manoeuvres and finding for example, the correct speed needed for loops and the minimum height required in the vertical plane to carry out the performance, especially in case of low cloud. Assuredly it will be seen that display flying can become an art giving equal pleasure and satisfaction to pilot and audience alike".

Had these words of wisdom been applied by many of the now deceased display pilots, some may have lived a lot longer. When will display pilots learn that safety is not negotiable, you're on the numbers or not – either the conditions are acceptable or they or not – it is a black and white case, there is no 'grey' in display flying.

CHAPTER 7

DISPLAY SPECIFICS

Former world champion, Lithuanian Jurgis Kairys maintains that every pilot has his own personal limits. For Jurgis, flying inverted with the fin six inches off the water is his personal low altitude limit. "I'm unable go any lower," he says. *(Jurgis Kairys)*

"There are three basic tenets of demonstration flying….discipline, knowledge and maturity. Discipline is the primary motivation during the demonstration. It is the force that compels you to enter each manoeuvre from well-known and practiced initial conditions. Intimate knowledge of aircraft's capabilities and personal maturity complement the discipline factor and ensure a reasonable compromise between over conservatism and edge of the envelope showmanship" (Pat Henry, former chief test pilot and F-15 Eagle demonstration pilot - McDonnell Aircraft Company)

INTRODUCTION

Exhibition flying may take on many different guises and the range of spectators watching and critiquing the displays may include the widest spectrum of aviation enthusiasts. Ranging from the uninformed general public who usually regard airshows as a 'fun' family outing, to the critical scrutiny of the test pilots and professional aerobatic pilots. Manoeuvring an aircraft to its limits within a confined airspace is without a doubt an extremely demanding and challenging task for any pilot. Any pilot can fly an aircraft along the runway at extremely low heights and perform steep turns, wingovers or loops, but the art of putting together a safe, imaginative, sensible and impressive flying display, is where the skill lies.

Selecting and designing the display routine is actually a choreographic art; anyone can string together several different manoeuvres and present it as a display, but not everyone can compile an aerial ballet that can capture and hold the attention of the entire spectrum of spectators in attendance. So what are the basic philosophies that display and demonstration pilots must specifically consider in preparation? What are the attributes of a display pilot and what are the safety considerations for flying certain manoeuvres and selecting a routine? What are the essential safety elements that should be addressed for low-level display and demonstration flying?

DISPLAY PILOT SELECTION CONSIDERATIONS

Consensus amongst veteran demonstration pilots in what constitutes the required make-up of the display pilot is ironically, relatively easy to achieve. Besides above average handling skills, the most important element must surely be the mental attitude, which could also be considered as maturity, and for maturity, read discipline, perfectionism and aggressiveness, in that order – a most appropriate way to describe the required personality and mental traits. By aggressiveness is implied 'positive' flying, not overconfidence. By maturity, implying that the display pilot must be able to handle the increased attention without having to continually 'prove' just how good; maturity in realising that in the face of competition against higher performance aircraft, remaining within the constraints of the aircraft's relative shortcomings in performance or handling qualities. Maturity in accepting the airshow regulations in force and complying with them and maturity in handling criticism, which can be especially insensitive if from colleagues or associates. In most cases, however, the criticism levelled at the display pilot should be not construed as personal, but rather as an honest attempt by fellow professionals striving to present a safe and aesthetically appealing display. So, besides the primary task of actually flying the display, the display pilot's responsibilities outside the direct scope of the display, can be intimidating.

Since the single most important role player in the successful presentation of a display flight is the "man behind the stick" – the demand for a high calibre pilot must be the highest priority. Most pilots possess the specific flying skills to make good display pilots but not many have the required interest or character profile to want to excel in this field of aviation. Brilliance at flying school, operational conversion course or even test pilots school plus excellent academic qualifications will be to no avail whatsoever unless, as the late John Derry said: "The pilot has the necessary temperament and keenness on flying itself with a total dedication. He must enjoy display flying – this is not a job for the man who shuts the hangar door abruptly at 5 pm in favour of his rose garden, golf clubs, vintage motorcars or who aspires to an isolated domestic life of bliss. To be worth his salt, the display pilot must become integrated with "the aircraft until it's almost engraved on his very heart."

Within the military environment, the display pilot is usually drawn from the ranks of the more senior members of the squadron, usually hand-picked by the Squadron Commander and recommended to the Base Commander for approval, provided the required hours on type and experience requirements are complied with. Only after vetting and confirmation by the direct higher headquarters or Command, is the specific pilot authorised to develop a sequence as the display pilot for that particular Arm of Service. In many cases, a ‘fly-off’ is held as one of the last tests against which a potential candidate is evaluated. Fortunately, the final decision is not only a ‘flying skills’ evaluation, the personality of the pilot must be considered against the public relations or sponsorship campaign since the display pilot will also act as the ambassador for a particular cause.

The display pilot must be capable of handling the ‘pressure’ of being a display pilot, not only the actual adrenalin rush of the display flight, but also accept the responsibility of the successes and failures of the display, keeping the public and the show organisers ‘happy’ and keeping up the ‘public relations pose’ which can be physically and mentally draining at times. Some of these aspects have no bearing on the display pilot’s ability to actually handle the aircraft, but rather the peripheral issues associated with airshow and demonstration flying, but which are equally important.

For major airshows, a reserve or substitute pilot should be available should the main pilot be otherwise detained for whatever reason. It makes good sense therefore, to always have two pilots assigned, each one flying; both pilots must however, meet the exact same requirements as for the main display pilot, if not, there is no display. Never make use of a ‘stand-in’ that has not progressed along the exact path of the primary display pilot. The non-flying pilot on the day of the display should be assigned the responsibility for briefings, public relations roles and manning the ground liaison radio during the display to assist not only in the handling of emergencies, but also monitoring the progress of the display and advising on relevant safety factors during the show.

With two pilots assigned to perform the same display routine, each pilot should, however, be given the freedom to perform individual manoeuvres according to each pilot’s personal preference, for example, right rolls versus left rolls, etc. The universal perception is that the test pilot will always provide an ‘awe inspiring show’, the test pilot is supposed to possess the knowledge and the flying skills to have achieved the top rung of the aviation specialist ladder, so why not? In truth, not all test pilots are good display or demonstration pilots, just as not all pilots are good instructor pilots; the passion must exist.

Those who are fortunate enough to experience the challenge of display flying know that success comes as much from dedication, self discipline and detailed planning, as it does from flair, skill and practice. The display pilot must be at home and naturally expert in display flying, one who enjoys the task and who is not always making excuses for how difficult it is; it must be part of his preferred lifestyle.

PLANNING CONSIDERATIONS

To establish the proper mental perspective for planning and practicing of a display routine, the same deliberate preparation and thorough analysis that precedes the most hazardous flight test phases such as flutter, loads and spin flight tests, should precede the development of the display routine. This preparation should include a thorough analytical assessment and safety review. It is prudent to consider the statement by Niel Anderson, F-16 demonstration pilot: “Approach demonstration flying with the identical and deliberate preparation that precedes the most difficult flight test phases. This includes the highest management approval of the flight routine, designation of pilot(s), contingency/weather conditions, safety aspects and most importantly, the training prerequisites in the display aircraft”.

It is during the planning phase that the exact objectives of the display must be formalised since the entire planning sequence must be driven by the specific objectives of the display. Whether it be commercial, military or even flight test product demonstration, competition aerobatics, military flypast or an appearance at a local ‘Fly-In’, the objectives must be clearly defined. Bob Hoover, famous American test pilot renowned for his superb demonstration of the Rockwell Commander at airshows worldwide, says: “All flight demonstration profiles should be well thought out in advance, with alternate flight profiles to be utilized under varying circumstances of inclement weather. Also, the demonstration pilot must know the overall design capability of the airplane and recognise his own limitations and avoid exceeding either."

One of the most critical areas which must be focussed on during sequence planning, is the "what if" emergency permutations. Each manoeuvre must be reviewed to determine the failure modes of equipment and the critical systems required to complete the manoeuvre; backup systems or escape manoeuvres must be planned for and practiced in the event that a critical system malfunctions inopportunely. Unfortunately, one of the variables in any display sequence is the unpredictable occurrence of the failure case or emergencies for which no other rule of thumb exists except 'to plan and practice for the unexpected'. In the case of formation aerobatic teams, each team member must have an 'exit manoeuvre' or 'break-away' planned for each sequence of the routine.

Wise words from Mr Jean Coureau, former Avions Marcel Dassault demonstration pilot: "The first consideration when planning a sequence is to consider the aircraft configuration, then the show programme, then test the show in front of well known censors. Comment and critique must be accepted and the sequence manipulated accordingly in an effort to improve the display appeal and enhance safety of flight until everyone is satisfied. Then print everything on your brain and never change any item during the real show".

During the planning phase, the topography must be studied comprehensively and the 'lay of the land' plotted out in an effort to identify potential obstructions, hazards to the flight path and any interaction topography may have with maintaining the display line. This includes consideration of the effects of orographic turbulence generated by adjacent mountainous features and also the effects of density altitude, particularly critical for formation aerobatic teams. There are many aerial display teams who have their home bases at or near sea-level and often arrive at an airshow location without having had much time for rehearsals only to find that the 5,000 ft elevation of the new display location generates density altitudes in excess of 8,000 feet – the reputation of the team could be severely jeopardised by not being able to accommodate the increased power required for the increased density altitude, embarrassing at the least.

Not forgetting of course, the prohibited, restricted, noise-abatement and built-up residential areas. It is highly desirable that the display pilot pays a visit to the display to view the spectator enclosures and pavilions and any restrictions that may interfere with the spectators appreciation of the display. It is also important to consider the most probable position of the sun at the scheduled time of the display and how it could adversely affect not only the display pilot, but also the spectator's viewing.

Many displays are flown over water, the spectators being located on the adjacent beach or land mass. The over water display presents its own particular topographical problems; besides trying to keep the show along the display line which physically does not exist on a water surface, the problem of depth perception, in itself, poses a significant hazard. With no peripheral cues and a flat surface, the human eye is unable to discriminate accurately and consistently. The human eye uses peripheral cues such as the size of known objects to estimate heights and distances but without such cues, the judgement of height above the surface is difficult, leading to poor anticipation and poor height estimation by the pilot, which is obviously inherently dangerous for low-level manoeuvring flight.

The haze caused by wind spray over the water surface, coupled with a lack of depth perception, can only be catered for by increasing the minimum altitude of the show to increase the safety margin. To assist in creating peripheral cues to facilitate depth perception, it can be especially helpful to use a line of boats provided by local fishermen, boating enthusiasts or search and rescue vessels to mark the display line. However, the limitations of depth perception over a water mass remains hazardous. Flt Lt Steve Johnson of the *Red Arrows* synchro-pair, ejected from his Hawk during a head-on opposition pass after clipping the 44 feet mast of a yacht anchored off Brighton during the annual Brighton display in 1981.

The display line chosen was over the sea, parallel to the coastline and between the Palace and West Piers. On the fourth opposition pass, No. 2 struck the mast of a yacht which, unnoticed, had motored slowly onto the previously clear display line. The yacht carried no sail at the time; with the aircraft out of control and almost inverted at now no more than 300 feet above sea-level, Sqn Ldr Johnson, ejected just three seconds after the collision. The authorised minimum height for the synchro pair at the time as 35 ft, a height considered to give a safe clearance and provide a spectacle for the public. There was however, no embargo on boat movements during the display and therefore no reason for the skipper of the yacht to suspect that his passage would obstruct the synchro-pair. The pilot did no see the slow-moving obstruction against the vertical pier structure and the sea and his aircraft struck the mast just 4 feet below its tip. Immediately after the accident, the minimum height for all *Red Arrows* displays was raised to 100 feet.

A temporary loss of reference, disorientation, disability, problem or loose article in the cockpit, remains a probability in the cause of the L-29 crash into the sea off Eastbourne (UK) in August 2000. Whatever occurred, the highly experienced pilot was nevertheless able to carry out a recovery from the dive to a wings level attitude but with insufficient height to affect the recovery pullout, the aircraft crashed into the sea, 800 meters off the coast. The 'display line' was established 230 metres offshore, parallel to the shoreline at Eastbourne and was marked by a number of orange buoys. The display datum point was the 'Wish Tower', an old Martello tower centrally located on the seafront from which an air traffic information service was provided. There were a number of safety boats available on the water, one of which was in radio contact with the shore. The written flying display regulations sent to pilots included the following note: "Pilots are reminded of the need for extra attention to height judgement when low flying over calm water and with an ill-defined horizon."

In this specific case, the pilot had carried out a number of training and practice flights over the sea in conditions similar to those at Eastbourne. It was noted that he tried to ensure when practising over the sea that sandbanks would be exposed to give a surface reference. It was also his usual practice, in conditions with poor visual reference, to use the attitude indicator to assist with checking pitch and roll attitudes during manoeuvres.

The video coverage of an RAF Nimrod crashing into Lake Ontario in September 1995 showed the aircraft in what looked like a near wings-level 25º nose-down attitude at approximately 700 feet and descending rapidly. The pitch attitude increased very briefly and very slightly, followed by an almost immediate stall break at about 500 ft or less and a continued descent into the water with little change in descent angle. It would seem that the pilot realized that the way things were going, they were going to hit the water, and pulled hard to try to prevent it. Was the cause in some way attributable to loss of spatial awareness as a result of operating over a water surface or just pure misjudgement of height due poor peripheral cues?

MANOEUVRE SELECTION CONSIDERATIONS

The display must not attempt to astonish or astound everyone in the crowd but should aim to capture the attention of the spectators by a professional display of the aircraft's capabilities, embracing the widest range of manoeuvres possible. Armed with the technical data for each manoeuvre, and if applicable, the company's or sponsor's requirements and marketing strategies, the basic routine can be compiled to best demonstrate the capabilities of The aircraft. It is imperative to avoid any manoeuvre that is likely to degenerate suddenly dangerously. Manoeuvres should be selected that willentertain and hold the spectators attention, but most importantly, the emphasis of the show routine should be designed demonstrate the aircraft's capabilities, not the pilot's skills.

Manoeuvre selection should consider that generally, horizontal turns show better and are safer if not flown at minimum altitude but rather with minimum radius, not maximum ‘g’ being the objective. Flying at a slightly reduced airspeed and g-level may result in the same impressive ‘minimum’ radius turn, but with less fatigue on the pilot. Vertical manoeuvres must address airspeeds, altitudes, and g-levels for entry at the manoeuvre checkpoints or “gates” throughout the sequence. Because it is most impressive, displays tend to commence with some type of vertical manoeuvre, either straight from take-off or otherwise. The noise and dramatic entrance is usually crowd-pleasing and seems to capture the imagination and attention of the spectators, setting the pace of the display. However, statistics indicate that the vertical manoeuvres are the most hazardous for high performance fighters, resulting in the highest number of destructive manoeuvres, which makes it particularly important that the display pilot ensures that sufficient escape options are available from vertical descending manoeuvres. Of the 38 Flight-into-Terrain accidents in Chapter 3, 71% of the accidents were in the vertical while only 16% were associated with rolling manoeuvres – certainly significant. Good energy management throughout and ‘gate conditions’, prevents the possibility of entering into a too-low and slow ‘coffin corner’.

Any descending manoeuvre must be started with an established altitude margin since intentional low altitude pullouts or extreme low altitude flying may look fairly spectacular and will have everyone talking in the pub, but only serves to increase the spectators’ anxiety and detracts from a professional display. There is also a significant difference in the skills required between a “shoot-up” and a professional display. Undisciplined low level flying is relatively easy, not only to fly, but also to cause an accident. The true professional utilises his skill to demonstrate the capabilities of the aircraft in a manner that impresses both enthusiast and specialist alike.

ROUTINE SELECTION CONSIDERATIONS

The first series of manoeuvres must be designed to grab the attention of the spectators because if you lose them at the start, it is highly unlikely that you will win their “hearts and minds” later on. Once you have the attention of the spectators, it is then necessary to keep them focussed, especially between manoeuvres. If the display is too wide and the aircraft disappears from view, boredom sets in and the fickle spectator may only look up as the noise of the aircraft passes by and all your display flying skills and hours of practice will be wasted. The repositioning and turn-around manoeuvres are therefore very important in maintaining the spectator’s interest.

The routine design should consider optimising the energy levels throughout the entire sequence. It is difficult to manage energy during specific manoeuvre since each manoeuvre has a specific energy budget that should not be tampered with during the actual display, therefore, the major effort of energy management is expended during the turn-around. Although not necessarily pertinent for the fourth generation and Unlimited Class aerobatic aircraft, for all lesser aircraft types, the turn-around is essentially a positioning manoeuvre and is particularly important because it is during this phase of the routine that the display pilot actually manages the energy before advancing to the next manoeuvre. It is that phase where energy is either built-up or bled. When matched with the actual manoeuvres, the repositioning manoeuvre should appear as an integral part of the display.

It is said that ‘hindsight is an exact science’ and is always easy to be wise after the accident, but the fact is that airshow routine design in modern times has become an art form on its own. It is no longer any number of manoeuvres strung together to fit into a given timeslot, but rather a scientific study that considers the objectives of the display or demonstration, be it entertainment, competition or commercial sales – that forms the basis of the sequence design. The manoeuvres are choreographed to match the various energy levels of the aircraft within the routine. With the routine chosen, consideration must be given to the influence of peripheral issues that significantly affect the display, including weather and topography.

The challenge for the routine selection is to retain interest that can be stimulated by alternating between vertical and horizontal manoeuvres interspersed with turn-around manoeuvres. Transition/repositioning manoeuvres must be utilised to maintain the show centre as primary reference with the show line as the secondary reference. The sequence and selection of manoeuvres should be arranged to give the display pilot an 'out' at any stage of the routine while avoiding the low altitude, 'Split-S' coffin corner type manoeuvres. In the case of afterburning jets with the associated high fuel burn-off rate, improved vertical performance can be obtained during the latter segment of the routine when the thrust-to-weight ratio has increased. Considerations for improving the aesthetic appeal of the routine should include operating the moving parts which move in normal flight or in combat conditions, i.e. combat slats, flaps, undercarriage, refuelling probe, canards, etc. Aircraft with a wing-sweep capability should have the wings moved in turns at different speeds, particularly in the high 'g' turns. Engine flexibility and response can be demonstrated with rapid engine accelerations at high angle of attack to show reliability and engine response characteristics.

To improve the T/W ratio, it is possible to decrease the aircraft's weight by removing a certain amount of non-essential components but on prototype aircraft, however, it would be much too expensive in time and effort to do so and could disrupt the programme schedule significantly. Knowledge of the weight and centre of gravity position for the display aircraft throughout the entire routine, is just as important as for scheduled operations, maybe even more so, since an aft CG increases agility on conventional aircraft designs and as such, the loading of the specific display configuration must be managed to provide the best handling qualities for the display flight.

Dassault's famed Jean Coreau has certain suggestions in this regard. "Obviously a take-off and a landing are an absolute minimum, therefore, minimum length take-off's and landings. After take-off, a steep angle climb away is usually more impressive than an acceleration to entry speed for an Immelman, which requires a high thrust-to-weight ratio to complete successfully. If the Immelman is the selected manoeuvre, the time for the acceleration should be kept to a minimum; a double Immelman is always impressive, but thereafter, it is difficult for the spectators to maintain visual on the display aircraft".

"Manoeuvres in a vertical plane best demonstrate the excess thrust, the handling qualities at low airspeed and lift performance (the radius of a loop being inversely proportional to the lift coefficient that the aircraft can safely demonstrate). Pulling more 'g' at lower airspeeds best demonstrates the best pitch agility while in level flight, a minimum radius turn is best obtained at 'corner speed,' the optimum maximum 'g' and maximum lift capability. A low speed, high angle of attack pass enables an assessment to be made of the aircraft's stability and control while tight turns at minimum radius may show both sustained turn capability and quality of lift and control boundaries".

Words of wisdom from Bill Humble, ex-Chief Test Pilot of Hawker Aircraft Ltd., whose Sea-Fury demonstrations fired the imagination: "The main purpose of a demonstration is to leave a lasting impression on the mind of the beholder. A complex system of aerobatics will not necessarily fit the bill. Aerobatic demonstrations should be worked up and practiced assiduously and on the day of the show, no attempt at improvisation should be made as this can lead to disaster".

PRACTICE

It goes without saying that the most important aspect of display flying is practice; every individual precision aerobatic manoeuvre must be practiced at every available opportunity so that the display pilot is always ready to work up for, and perform the demonstration. Legendary British test pilot Bill Bedford, a survivor of more than 200 airshow's advice to any and every demonstration pilot is that: "Practice is the demonstration pilot's life insurance policy. Renew the premium regularly."

The actual practice and build-up programme of the sequence must be commenced as early as possible to cater for possible weather, aircraft unserviceabilities or domestic issues. The display sequence practice must obviously begin at higher altitudes gradually working the height down as the competency improves and confidence increases. Demonstration pilots questioned by the SETP in a survey conducted by the Airshow Safety Committee concluded that a minimum of ten to thirty practice sessions were required to become proficient with a new airshow sequence. A rough 'rule of thumb' for a military fast jet pilot with access to a modern, high fidelity simulator, is approximately twenty simulator sorties to ensure that the pilot is totally familiar with the manoeuvres before proceeding to first flight.

Once the display pilot is satisfied with the simulator sorties, the display can be taken to the air and gradually worked down from 5,000 ft (1,500m) in stages. Approximately four sorties at 5,000 feet, four sorties at 1,500 feet, four sorties at 1,000 feet (300 m) and finally down to 500 feet (150m). There is no hard and fast rule here, the amount of practice required is a function of how much continuation training and preparation has preceded the build-up to the display practice. A well-practiced, current pilot may require significantly less practice sessions. Importantly, don't expect the first practice sessions to be an instant success, criticism will be delivered and continuous improvements will have to be incorporated to streamline the routine. This phase can certainly be one of the most frustrating as all involved comment and criticise the practice and your hard work in developing a display sequence – remember, its not personal.

Nevertheless, by modern day standards, these practice sessions constitute an immense investment in time and money by any Contractor, Sponsor or aircraft owner and can be outside the realms of programme management schedules or costs for private ownership. In such cases where expensive practice time is required, consideration should be given to using 'low cost' supplementary aircraft to achieve this low level flying familiarity, thereby allowing a more cost effective transition to the more expensive aircraft. However, a word of extreme caution is prudent – the category of aircraft, more particularly the T/W and agility characteristics should approach those of the display aircraft or else not only is the value of the training negated, but the safety margins may be jeopardised due to non-comparability or inadequate representivity in performance.

Interestingly enough, many pilots who have flown air-to-air combat missions consider display flying as being as fatiguing as an air combat manoeuvring sortie, the 'g' spectrum and the adrenalin induced by "close ground proximity" operations being very similar to the risks of being shot at by the enemy. Fatigue and stress goes hand-in-hand with display flying which implies that the practice sessions should be controlled and monitored to prevent such adverse effects. To minimize the effects of long-term fatigue, a recommended rate is to limit total practice sessions and actual airshows to two shows per day with a maximum of ten airshow sessions per week. Most importantly, management's responsibility should focus on reducing all extra-mural activities and routine work during the display-flying phase to allow the pilot to focus completely on the task at hand and not be burdened with peripheral issues that may cause distraction. Agreed, this idealistic approach is not realistic considering the demands and the pace of modern society, however, the administrative and airshow management overload on the pilot's the SAAF Museum Spitfire accident in 2000 and also the P-38 Lightning at Duxford in 1996, could in all likelihood contributed to the accidents, indirectly, at least.

Regular practice sessions should also include g-fitness routines and pilot familiarization with, and recognition of aircraft characteristics arising from each particular manoeuvre. More specifically, recognition of aircraft stall, departure and recovery characteristics, in particular the instant recognition of the accelerated stall is of paramount importance. Recovery height required for pullouts from dives at various angles, the 'stick-force-per-g' and the pitch response characteristics for the specific aircraft type should be understood and practiced. The aircraft's roll response at the different critical parts of the show routine should be practiced, angular acceleration, adverse yaw, pitch attitude effects due to rolling manoeuvres, the effect of rudder inputs and inertia cross-coupling are all essential considerations. Recovery from the entire permutation of possible unusual attitudes that could be encountered should be practiced for all the planned manoeuvres to cater for aborted manoeuvres resulting from inadvertent entry into cloud or possibly, emergencies. Escape manoeuvres must also be practiced, it is pointless just having an escape manoeuvre planned 'on paper' – the last thing a display pilot needs is to have to fly the emergency escape manoeuvre for the first time during an actual airshow or demonstration flight.

During rehearsals, a knowledgeable ground observer must be located centrally in the spectator area to monitor and make a constructive analysis and critique of each manoeuvre. The display pilot must invite criticism, as difficult as it may be to accept, and if there is a problem in terms of the skills required which cannot be resolved, the pilot should be mature enough to either hand over the flight demonstration to someone else with the ability to conduct the required flight display profiles or consider cutting the particular sequence from the routine.

Rehearsals should be flown over the actual display location, not as in the case of the Ukrainian Su-27 where the unfortunate pilots saw the display arena for the first time on the actual show day. Running in to commence the show, the two pilots first spent a short period trying to find the spectator enclosures and determine a show line and the show centre– a bit late in the planning sequence and possibly one of the main contributors to their poor maintenance of the display line. It is just common sense that the rehearsals should be flown as near to the actual time-of-day as possible to get a realistic feel for the environment and particularly sun position and its effect on visibility. It is not difficult for a display pilot to become disorientated in a strange display arena, particularly if the airfield has several different runways and offset display lines.

Disorientation was a contributory cause in the crash of the USAF F-16 in Kingsville (USA) in which a highly experienced combat and display pilot possibly became disorientated. The accident investigator concluded that the pilot focused too much attention on ground references, leading him to begin the Split-S from an altitude at which it couldn't be safety completed. Strong winds and multiple crossing runways could have caused difficulty in keeping the aircraft within the display arena. Then there was the case of the *Blue Angels* leader, Cmdr Donnie Cochrane who in 1995, actually suspended the *Angels* programme to take the team back into training after he had lined up on the wrong runway during a low-level manoeuvre at Oceana Naval Air Station in Virginia Beach, – these things happen to the best as well –the inability of the human physiology to handle the high information rate of the high speed low-level manoeuvring does not discriminate, all pilots are susceptible.

Rehearsals should, if at all possible, be flown in the actual aircraft which will be flown in the display; at low-altitude it is necessary to be in 'touch' with the particular aircraft, it's handling and performance characteristics, engine response and acceleration time and fuel consumption. The middle of the sequence is not a good time to begin wondering whether the noises or buffeting of the airframe is significant or not.

In keeping with most modern training techniques, the use of video is considered essential as a teaching aid to the display pilot, particularly in facilitating debriefing sessions. The use of video externally, combined with the Heads-up-Display video available in some aircraft, serves as an ideal teaching tool and can also assist in any accident investigation. Ideally, the video should be made against a specific ground reference feature to improve orientation for post flight analysis and debriefing. Proper configuration management of the HUD videotapes must, of course, be exercised so as to enable the building a history of skills growth.

The luxury of high fidelity simulators exists only for the chosen few, those display pilots flying the most modern generation military aircraft or airliners. With the development of more sophisticated and capable simulators, the technical and qualitative assessment of the show routine can be performed and verified in such simulators. The quantification of entry and exit parameters, the time for each manoeuvre, the effect of crosswinds, practicing of emergencies and system failures and the fuel used, can be determined. It is also possible to download the planned flight profile into the aircraft's navigation and weapons system for display to the pilot in the Heads-Up Display (HUD) providing an energy management tool that generates steering cues to the pilot in the HUD.

The lack of true fidelity and the dynamic effects of acceleration, is a major shortcoming of simulators making it impossible to provide the peripheral motion and feel cues necessary to utilise this capability effectively. However worthwhile simulators may be as teaching tools, simulation cannot and must obviously not be used as a substitute for actual practice of the show routine.

Renowned for his earlier impressive Canberra and Lightning demonstrations, Roland Beamont, ex-English Electric test pilot's advice was: "Practice individual manoeuvres throughout the year – then they will come together better and more safely for air displays. Know your aircraft, its 'hard limits' and its safe margins, from critical handling features such as stall, to inertia cross coupling departures. Don't compete shot for shot with aircraft that have obvious superior performance in some aspects. Don't ignore the simple basics. A low fast pass should be as low and as fast as the regulations and aircraft permit. A tight 360º should be the minimum radius practical under the circumstances, where possible setting thrust = drag and controlling the radius using 'g' and maximum power. Use maximum rates in bank changes, positioning turns and pull-ups. Smooth precision flying feels nice but often looks less impressive than 'horsing it around'. Above all, stay safe. Keep to your practiced routine and don't ever try and improvise the handling and performance boundaries".

In fighter pilot parlance, there is the phrase: "Never engage the enemy on his terms" and by similar analogy, the display pilot should fly the display on his terms, not that of the competition. Lastly, what is it that causes fear in the human? The unknown, and this fear can only be overcome by confidence gained from the knowledge of exposure to the various permutations of failure cases. Knowledge gained from practice, the knowledge of knowing exactly what is planned and how to fly the plan and handle all possible contingencies, will provide the confidence for the well-practiced display pilot enabling the pilot to perform at his best. When it gets to display flying it would not be out of order to quote an earlier generation world golf champion Gary Player, who said: "the more I practice, the luckier I get!"

REGULATIONS

As extraordinary as it may sound, throughout the entire airshow world, no consistent and uniform set of regulations exists governing the "do's and don'ts" of display flying. Each country, each airfield and even each air force, has different regulations in place. It is imperative therefore that the display pilot study's the regulations in existence at the particular display location – in many cases, the regulations may have been compiled many years previously and are no longer relevant in certain instances and could even be dangerous or no longer applicable to a specific class of aircraft.

It is important to realise and argue against unrealistic regulations that in themselves may be dangerous. In today's litigious and regulatory society, life has become complex; there are regulations to cover most contingencies – it is essential to understand any waivers or concessions granted with respect to non-compliance with regulations, lest the aerospace Company, air force or the particular Government be held responsible for any litigation costs. Throughout the history of airshows, there have been instances of pilots 'breaking the rules', rules imposed for reasons of flight and spectator safety. Why do pilots do that knowing the inherent dangers of display flying? Prior to the 1988 Ramstein tragedy, the rules in the USA already prohibited flying directly at the crowd and the Italian *Frecce Tricolori* aerobatic team was arguably the most exciting demonstration team in the world. However, the 'rules' the *Frecci*

Tricolori reportedly flew at Moffet Field, California on their 1985 USA tour is a point in question. They flew three consecutive days, and flew the quite appropriately named “arrow through the heart” manoeuvre on all three days. Therefore, at least in some parts of the USA, they bent the rules and got away with it but the bottom line is, and has always been local authority, and the willingness to conform and enforce. There is no doubt that the rules are ‘bent’ at various venues throughout the world display flying circuits.

From a flying supervisory viewpoint RIAT Fairford 2003 went reasonably well although one light aircraft formation was withdrawn for blatantly ignoring the height and lateral requirements on the practice. After a full debriefing they agreed to comply - and then did precisely the same on the first day of the show. The Flying Control Committee also sent off a "letter of displeasure" to the Embassy of one of the international teams for again flouting the agreed requirements – they consistently flew over the crowd – once again before and after individual briefs.

However, today, having hopefully learnt from the lessons of the past, aerobatic teams and display pilots try to fly as safe a show as is humanly possible. But, from time to time, even the top formation aerobatic teams have cut a thin line. Mistakes are made in every show flown, teams film each show and run the tape during the de-brief. Formation aerobatic team members can get quite candid and direct in these sessions as each pilot is totally free to criticize the others – they take this quite seriously since failure to heed warnings can have catastrophic results.

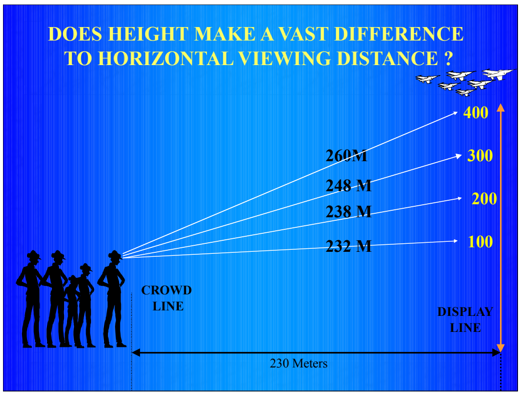
Most of the time it’s something small like a slight position error, but occasionally from time to time, a solo can get way off his line and ‘bend it’ a bit trying to re-sequence with the main formation. It is generally these isolated events that make up the experiences related by airshow spectators watching the show that tell about the team flying ‘over the crowd’. These things happen, not necessarily on purpose, but it happens!

Not only do regulations impose a minimum horizontal standoff distance between the aircraft and the crowd line, but also a minimum height above ground level, depending on the aircraft category, flight profile and sequence. The demands of dynamic manoeuvring of an aircraft in three dimensions close to the ground requires a high level of experience but more importantly, skill. Although there are minor differences between the regulations imposed by different countries, single seat aircraft are generally limited to a minimum altitude of 100 ft (30 metres – non manoeuvring) for level flypasts and 200 ft for manoeuvring profiles; formation aerobatics teams are limited to 200 ft. To get a feel for the dynamics of the space and time problem, consider the very simple example of an aircraft in a vertical descent at a transient rate of descent of 6,000 ft per minute, (100 ft per second), not uncommon for a high performance aircraft. In theory, it would take only two seconds to traverse the 200 ft safety buffer if not recovered early enough from the dive, and it is this that makes anticipation of the aircraft’s energy levels, more particularly its momentum, especially critical. It must be reiterated, therefore, that these physical limits are real and critical, there is zero error margin.

The average distance between spectators at international airshows was measured at approximately 70 cms (2.3 feet). (SAAF 80)

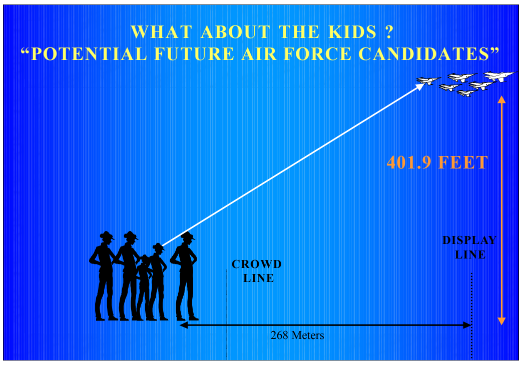
The height limit of a single aircraft display to a minimum of a 100 feet above ground level, definitely cannot stand as a rule for all aircraft categories used at airshows. As a rather extreme example, a B-52 at even 400 feet cannot try to do the F-14 show – it just cannot work at all. The minimum altitude has to be a function of the aircraft type, category and manoeuvrability. An aspect often lost on the display pilot is the visibility problem for the spectator once the aircraft descends below approximately 100 ft. Those with ringside seats, which are only a small percentage of the spectator population, have no problems, but those from the third row backwards, see virtually nothing of the display aircraft.

In contrast with the universally accepted procedure of imposing minimum height limitations on the display pilots based on the pilot's individual Display Authority, the South African Air Force Safety Directorate analysed the minimum altitude requirements from the spectators viewpoint based on the criteria of making as much of the airshow visible to the 'smaller people' and children as possible – after all, the justification for hosting a military airshow is exposure and recruitment. Based on measurements takenof airshow crowds within the spectators enclosure at two international airshows hosted at AFB Waterkloof, it was calculated that the average distance between spectators, was approximately 2.3 feet.



There is no significant difference in line of sight distance over the relatively short range of the internationally accepted 230 metres lateral Minimum Separation Distance. (SAAF DFS)

It was furthermore deduced that the angle required to look over the head of the spectator in front was approximately 10.3° and with a crowd line located at 218 metres, the minimum flypast altitude was 402 feet, eliminating the requirement for pilots to down to their minimum Display Authority limitations. There is of course always a tendency for spectators to attempt to get to the front of the crowd line, often squeezing the minimum separation distance between individuals to less than 2.3 feet instead of just accepting the move backwards from the spectator line. Fanning out back from the spectator line, the increase in horizontal viewing distance when watching the show 50 feet back from the spectator line is not considered significant, in fact, the line of sight distance over 230 metres increases by only 28 metres for an aircraft flying at 400 feet.



To cater for the case of children located 50 metres back from the show line, the minimum altitude calculated was 402 feet. (SAAF DFS)

In terms the regulations governing formation aerobatics teams, the *Red Arrows* typically do not fly directly over the crowd below 1,000 feet although manoeuvres in front of and parallel to the crowd, can be flown down to 200 feet. The 'Synchro-Pair' is allowed down to 100 feet in straight and level flight in front of and parallel to the crowd line and inverted flight is not flown below 150 feet above the ground. These and other similar restrictions attempt to eliminate the possibility of an accident similar to the one at Ramstein 1988.

Today, more than ever before, a major challenge exists for airshow regulators - the problem involves the areas surrounding the airports where the shows are flown and the formulation of adequate regulations to protect the general public and private property on the ground. If and aircraft comes apart, or has a mid-air, the chances are up for grabs for the people in the fringe areas. Besides the several hundred spectators that have been killed or injured on airfields over the years, there are several examples of just how dangerous the airshow environment can be when things go wrong, not only for the pilots, but also for the uninvolved public that happen to be in the vicinity of the airfield.

Ideally, that area around a display-flying zone could continue its airshows by keeping a wide area around the station, development-free. Since that is an impossibility, officials must balance how important the show is and how much danger, if any, the nearby homes are in. Most people recognize military bases and airfields as a real asset and restrictions on future airshows will have to be carefully considered. The events usually help residents connect with the base and keep the station or airfield as part of the community, an important goal, but in the end, it's basically a public relations thing.

In keeping with best practice, the provision of safety regulations for the surrounding areas is especially complex for the more modern well-developed areas and airfields. Farnborough is a typical example in which pilots are obligated to fly all profiles that have a track towards a built-up area, in an upward flight trajectory. This regulation is imposed not only for noise abatement purposes but also to increase the potential energy of the aircraft in the event of an aircraft emergency or failure. Downward manoeuvres are only permitted once the turn-around over the built-up area is complete and the flight path vector is pointing towards the airfield.

The worst case example of collateral deaths and injury was the 1973 crash of the Russian Tu-144 at the Paris Airshow that killed eight and injured sixty members of the public in a nearby village. The Indian Air Force Mirage 2000 solo display crash at New Delhi during the 1989 Air Force Day celebration air display, killed two and injured twenty members of the public. The situation could have been particularly devastating in the case of the USAF F-117 in-flight structural failure during the 1997 Baltimore Airshow. The aircraft landed in a densely populated residential area injuring only four people, most of the inhabitants were fortunately away at the time of the crash. The Hawk 200 crash in Slovakia's SIAD '99 not only killed one spectator on the airfield but the crash debris penetrated the airfield fence injuring four members of the public outside the confines of the airfield.

The mid-air collision between the two Indian Navy IL-38 maritime patrol aircraft during the formation display practice for the 25th anniversary of 315 Squadron in 2002, resulted in the wreckage of one of the aircraft landing on a residential site killing three and injuring seven labourers on a construction site. Collateral deaths and public property damage poses a significant threat to airshows, more so than for aviation in general. The argument arises from the fact that the risks of airshow flying are obviously higher than that of general aviation and a case could be made against show organisers on the grounds of the increased level of danger posed. Airshows are after all regarded as 'entertainment' while general aviation is regarded as an essential transport capability.

Strict enforcement of regulations by the Flying Control Committee most certainly played a significant role in reducing collateral damage and possible spectator fatalities when the Su-30MK crashed at the Paris Airshow on 12 June 1999. In an article published in *AW&ST, 06-28-99, pp. 45-46,* it was reported that although test pilot Viacheslav Averyanov and navigator Vladimir Shendrikh had complied with the routine they had demonstrated during rehearsal flights on June 10 - 11, the aircraft deviated significantly from the planned display flight's axis on the show day. The pilot said he was disoriented by the aircraft's unforeseen northeast heading, notwithstanding, he remained within the limits of the safety perimeter.

After two downline rolls, the aircraft started approaching built-up areas in the nearby city of Dugny. During the third roll, the pilot aborted the roll in an effort to stay within the limits of the prescribed safety boundaries and headed in the opposite direction. According to investigators, after Averyanov interrupted the third roll, he attempted to pull out and recover from the descent, but with insufficient height. During the manoeuvre, the aircraft lost 800 feet in altitude, speed

decreased to 250 kts and the pilot recovered to a nearly horizontal flight path. The rear fuselage struck the ground and the aircraft skidded on the grass for 30 metres, causing the port engine's jet-pipe to break away-before the aircraft rebounded into the air. General Designer Mikhail Simonov had initially attributed the mishap to pilot error before incriminating a shortened flight routine ordered by the air show's organizers (AW&ST June 21, p. 28).
"If the pilot had not aborted the manoeuvre, the aircraft would have flown over the Dugny neighbourhood below the minimum regulatory altitude and the pilot probably would have been banned from additional flight presentations. In response to the residents' request to limit noise and increase safety, the minimum altitude of aircraft over Dugny during the flight display that year had been increased to 1,000 feet, up from 300 feet.

Although show organisers have as their main concern the safety of spectators, incidents sometime happen outside the control of the organisers. On one of the pre-show practice days at RIAT 2001, some over enthusiastic amateur photographers foolishly decided to stand directly behind the B-1B bomber outside the perimeter fence at RAF Cottesmore, presumably to get better photographs. The 123,000 lbs of thrust unleashed by the afterburner light-up was sufficient to cause a number of injuries – the show organisers had not taken any precautions to address the foolishness of 'non-paying spectators' outside the airfield perimeter.

According to the International Council of Airshows, strictly enforced airshow regulations in the United States and Canada would prevent the type of accident that occurred when the Su-27 crashed at an airshow in western Ukraine. A strict prohibition on aerobatic manoeuvres that directed the energy of the performing aircraft toward the spectators, a 1,500 feet minimum setback distance between the performing aircraft and the audience, and a demanding aerobatic flight evaluation programme, were at the heart of an airshow safety programme in the United States and Canada. This programme had resulted in the elimination of spectator fatalities since the regulations were put in place more than fifty years ago. The last spectator fatality in North America in 1952 prompted the development of the regulations currently in place.

North American airshow professionals and federal regulators pledged any assistance necessary to help their European airshow colleagues establish a North American-style airshow safety programme, a programme that had established the benchmark for airshow safety in the world. Displays in Western Europe and the US are governed by sheaves of regulations, handbooks, licences and monitoring systems. Crowd exclusion zones are enforced and pilots are barred from carrying out manoeuvres below a certain height, even flying towards the spectators is banned. The ethos is one of assuming that the million-to-one chance of an accident might actually happen and the crowds must therefore be protected. But in some other parts of the world, displays are organised on the 'nothing will go wrong' theory. People don't always think through what could conceivably go wrong; in some countries there could be accidents waiting to happen.

Most of the heavily regulated countries have tightened the rules after their own bitter experiences. For instance, in the UK, it was a fatal crash at Farnborough airshow in 1952 which sparked heavy rewriting of the rules. In Germany it was the 1988 disaster at Ramstein Air Base which killed sixty-nine spectators that led to tough new regulations but considering mankind's past performance, it is probably true that there first needs to be an accident to concentrate minds.

A journalist who attended an airshow in Japan the day after the Ukraine tragedy told BBC News Online that the Japanese military display team, *Blue Impulse* , were performing their display directly over the crowd. The Air Display Association Europe, which works with airshow organisers, said the former Soviet countries were among the worst offenders for relaxed regulations. "We believe that the former Soviet states don't fly to the same safety standards as we do," said chairman Wing Commander John Davis. "We have always been concerned to get UK and European regulations as far-east as possible and I hope that as a result of this crash, the Ukrainians will be looking westwards," he added.

"Most Western European countries adhere to a set of harmonised guidelines published in 1995, or are working towards enforcing the guidelines. Every part of safety is laid down. The regulations imposed require minimum distances from the spectator line, straight flights 230 metres from the crowd, manoeuvres 450 metres from the crowd with a minimum altitude for aerobatics limited to 500 feet above ground level. Additionally, the Display Safety Committee evaluates each display pilot's plans and flying display and has the power to 'red card' pilots. Even the best-regulated airshows cannot be completely free of risk, things can always go wrong, but in Western Europe, all reasonable precautions short of not having an airshow, have been taken".

Ukrainian regulations stipulated that demonstrations must not be performed at an altitude lower than 400m (1,300 feet), said former Ukrainian fighter pilot Colonel Alexei Melnik. "But the pilots might have been under pressure to impress their commanders with their aerobatic skills", he said. Much speculation was focused on whether the pilots lost power at a crucial stage in the manoeuvre, but the position of the crowd and the altitude of the manoeuvre were also key to the inquiry. In Ukraine it was unclear exactly what regulations were in place, or whether they were being adhered to. But Ukrainian experts were quick to stress that the rules in place may not have been followed at Lviv. Former Russian air force chief Anatoly Kornukov was quoted after the tragedy as saying: "It was 'inexcusably risky' to have planes flying directly over the crowd. It was against all organisational rules," he told Russia's Interfax news agency.

In the case of helicopters, the size and shape of manoeuvring boundaries shrink and so do the regulations governing Minimum Separation Distance (MSD). Typically, straight and level flypasts at up to 20º bank angle must be performed above 50 feet MSD while aerobatics by helicopters are permitted only on helicopters certified as having a capability proven to the satisfaction of the Flying Control Committee. In turn, aerobatics and rolling manoeuvres must be executed and completed above 500 feet MSD with no more than one roll permitted during any one pass. This particular regulation no doubt had its origin in the Farnborough Airshow crash in 1974 when the S-67 prototype helicopter started the sequence of consecutive rolls too low and hit the ground on exit from the last of the two rolls.

All other manoeuvres must be completed above 100 feet MSD except hovering and transition manoeuvres, which may be performed below 100 feet MSD. In terms of the minimum lateral separation, aircraft or helicopters are not to be flown closer to the spectator's enclosure than the 230 metres Display Line. Lastly, to prevent inertially distributed crash damage, when flying at speeds above 300 KIAS, aircraft are not to be turned towards the Spectator Enclosures unless the turn is completed no closer than 450 metres away from the Spectators Enclosures.

Organisers and Flying Control Committees exercise a certain amount of common sense in the application of MSD regulations, for example, flying over the crowd at 6,000 feet is unlikely to end in a crash directly into the crowd (who are, in fact, one nautical mile away at that height). There should be no need to overfly the crowd at lower levels. Following the *Frecce Trico* lori incident at USAF Ramstein, Germany (previously the world's worst airshow accident), the 'no overflight of the crowd' rule was brought into force. The British *Red Arrows* changed their display after the change in rules and if the world's premier aerobatic display team could do this, then the rest of the display fraternity can.

'Anoraks' would have noticed some years ago that the *Thunderbirds* removed the 'high AOA pass, the Low Bomb Burst (energy at the crowd), Delta Cloverloop with 'blue out' (energy at the crowd) and the cross-over break from behind the line...with 'energy' at the cross away from the crowd. No more 6-ship 'bon-ton' either due to wake turbulence on the trailing solos....just to name a few but it's still a great show. At one of the earlier Dayton Airshows, the *Thunderbirds* solo reportedly came directly from behind the crowd, overhead the spectators and then turned left to rejoin. The difference was that the aircraft was going straight and level as it came over, very fast, but no aerobatics.

Notwithstanding the foregoing comments, at an airshow in Europe in 2001, pilots were briefed that all the rules would be strictly enforced by the Flying Control Committee. First on the programme was one of the country's solo fast jets - not only did the aircraft arrive from 'crowd-rear', but also overflew a specified very sensitive part of the military base at which the airshow was hosted. The briefing specifically stipulated that overflying the prohibited area was against the regulations. Then, their national display team arrived from behind the crowd. When this was mentioned to the organisers, they just gave a 'shrug'. One display pilot reported: "I also experienced a similar attitude more recently outside of Europe. Some, and it is only a few organisers, are big on quoting and emphasising the rules to the visitors, but do not have the 'balls' to stand up to their national display team 'heroes' when they transgress the same rules. It's far better to put in place and enforce strict rules on air display routines to avoid flying over the crowd during the display routine. The safety regime should be such that any flameout, mechanical or structural failure will result in an aircraft crash in a part of the airfield not open to the spectators or the public".

In discussion with a veteran American display pilot: "Thinking back to my earlier days on the airshow circuit, I am always amused at how the FAA used to crawl up our ass at the beginning of show season asking various questions about our manoeuvres, almost in a 'hatchet man' fashion. I always tried to be friendly and courteous, of course. They are really good guys overall, but, when they got cocky and crossed the line in a realm they knew nothing about, trying to 'corner' me on some safety issue, I'd be 'blunt' and sort of an asshole". "Look pal, don't even question the safety of this display, mechanical failure...sure, it happens.... nothing I can do about that. However, I know our maintainers are the best in the world".

"However, you can't do anything about simple airframe fatigue if some insidious 'crack' causes material failure. What really chaps my ass is how they crawl around to find a flaw in the demo...and they don't do jack shit about 'that act' which does a 'mid air transfer' between a helicopter and a biplane right at show centre. They're going to 'splat' that poor bastard on the tarmac one-day. Or, how they don't put tougher controls on that 'friggin' jet car that will certainly blow a tire one day and go barrelling into the crowd. Now...if you'll excuse me....The jet car did indeed blow a tire years later. What hunk of danger that act was. The FAA typically stayed away from me the whole weekend after that. Usually, I'd go right up to them following the demo...right in their face....any problems with the show?" They'd just look at me and nod, no.... I'm an intimidating bastard when people question the formation aerobatic safety record, our procedures and our abort procedures when I see 'clown acts' get away with MURDER.

In another accident on 22 March 2003, a late Saturday airshow crash at Tyndall AFB claimed the life of a talented civilian pilot flying a Technoavia SP-95 aerobatic aircraft. Chris Smisson, a highly accomplished member of the *Airshow Unlimited* Airshow team, flying at the Gulf Coast Salute 2003 Airshow at Tyndall Air Force Base, was killed in a 'near vertical' impact that reportedly occurred as part of a 'faux race' between his aircraft and a jet-powered truck. No spectators on the ground were injured. One spectator described the impact as "head first," and other reports indicated that the aircraft was coming out of a loop supposedly in preparation for a high-speed low pass as part of the aforementioned race, when the accident occurred.

Regulatory authorities at airshows impose limitations through the Flying Control Committee to permit skilful and convincing displays. However, flight safety and the safety of the public are always of paramount performance. Of the thirty-nine Flight-into-Terrain accidents of the 118 airshow accidents analysed in Chapter, twenty-seven accidents (69%) were in the vertical and six (15%) were associated with low-level rolling manoeuvres. One of the more disconcerting factors is the relatively high percentage of downline multiple rolls that ended in tragedy and in the analysis, six of the twenty-seven (22%) of the fatal vertical accidents were attributable to downline rolls.

For the purposes of regulation, and once again induced by airshow accidents, slow speed, high angle of attack flypasts are also regarded as 'aerobatic manoeuvres'. The risks associated with low speed flypasts spring mainly from a controllability problem and then of course engine performance at high angles of attack. A classic example of this type of accident is the Canadair F-86E Sabre Mk 6 during a low speed flypast in June 1999 at the Bonanza airshow in New Jersey, USA. The Korean war-era swept-wing jet reportedly went out of control after a low-speed, low-altitude pass down the airport's single runway. A witness, standing approximately 2,000 feet from the accident site, watched the aircraft take-off, and perform several manoeuvres before flying a 'slow', high-alpha pass to the west at approximately 200 feet agl. As the aircraft passed in front of the witness, it slowed, and started to sink. The aircraft's pitch attitude increased, and the witness heard an increase in power, followed by a bang, described as consistent with a 'compressor stall.'

There was of course also the USN F-14 on 18 June 2000 in which the pilot and radar intercept officer died aboard a F-14 Tomcat when it crashed as horrified airshow spectators looked on. The aircraft was the second-to-last performance at the annual Willow Grove 2000 'Sounds of Freedom' airshow. The 'Tomcat' was demonstrating a landing 'wave-off' manoeuvre, approaching at slow speed to simulate a landing and then circling for another attempt as if 'waved-off' from the first. Taking full power, the aircraft rolled inverted in what appeared to be stable flight for a couple of seconds, rolled right side up then rolled into a 90º bank level turn. The nose pitched down sharply while still in a steep bank and the aircraft then rolled to a nearly wings-level attitude but in unrecoverable flight conditions. It is not without reason that minimum altitude restrictions are imposed. To be sure, airshow regulatory authorities have learned from past lessons and have been forced to regulate pilots for their own, and the spectator's safety benefits. Numerous other regulations exist which prohibit the in-flight shutdown of engines, intentional asymmetric flying, exceeding maximum airspeeds of M0.92/600 kts, flying over the spectator enclosure, the use of reheat/afterburners over built-up areas and the dropping of chaff and flares.

Strangely, many pilots have mixed feelings about airshows in general; they love doing them, and never willingly break the safety limits. That being said, many have been involved in incidents that could very easily have resulted in loss of life. The dedication to flying the safest show possible and to safety in general to date, has resulted in the zero net loss of life to spectators viewing the airshows in the USA and the relatively low number of spectator fatalities worldwide.

DISCIPLINE

The importance of a disciplined competitive display is recognised but one must also, at all costs, avoid being "suckered" into trying impromptu manoeuvres to outdo a rival Company/competitor, otherwise a serious risk of emulating the Tu-144 tragedy at Paris Airshow in 1973 exists. Management pressure or even personal ego, commonly referred to as the "testosterone level", has in many cases driven highly experienced pilots to irrational behaviour with disastrous consequences. Bob Hoover, when watching the Soviet pilot demonstrating the Tu-144 at the Paris Airshow in 1973, said: "If that guy keeps flying like that, he is going to kill himself", which he did on the last day of the airshow but also killed eight members of the public in an adjacent village.

The importance of a disciplined, competitive display cannot be overemphasised. Never be persuaded against your better judgement to get involved in a highly marginal display and never, ever change any basic manoeuvre during the display unless it is absolutely impossible not to do otherwise. That said, a pilot must be ready to make adjustments if unexpected circumstances arise that could adversely affect the safety of flight.

To quote the RAF's Derek Fitzsimmons, Hawk display pilot: "Low-level aerobatics requires good physical and mental capabilities; concentration at low-level being absolutely paramount. I have two golden rules: Firstly, never be persuaded into displaying in unsuitable weather, therefore, have routines for low cloud and/or poor visibility and, if in doubt which to use, always go for the safest. Secondly, never enter a vertical or looping manoeuvre with insufficient speed. By a steady progression from a safe height to display height, the pilot knows his limits. There is no point in exceeding these limits just because you are in front of a large audience."

FLIGHT ENVELOPE

The aircraft must obviously be displayed within the cleared flight envelope. While this is not usually a problem for the operational pilot, for the test pilot, severe restrictions on the manoeuvring potential may exist on a prototype aircraft during the early phases of the flight test programme. The display pilot must ensure that the show is constrained within a comfortable airspeed, 'g' and angle of attack regime. If the flight envelope cannot be extended to a comfortable level of airspeed before the show, a programme must be established in which the pilot can easily manage the aircraft within the constraints by avoiding any manoeuvre or profile that can degenerate and require more 'g's or AOA to recover.

The SAAB JAS 39 Gripen that crashed on Sunday, 8 August 1999 during an air display over central Stockholm, was the direct result of a pilot induced oscillation (PIO). The PIO was reportedly caused by the pilot reaching a flight envelope limit which engineering were aware of, but considered the probability of occurrence insignificantly small. In fact, the pilot entered a segment of the flight envelope that had not yet even been tested; fortunately there was no fatalities or significant collateral damage. The claims that could have arisen from the public against the Manufacturer for knowingly displaying an aircraft to a public audience could have had catastrophic effects on the Manufacturer. The last place a display pilot needs to find out that envelope limits have been exceeded, is during the actual display.

Another important consideration; never fly an unserviceable aircraft, irrespective of whether the problem is airframe, engine or systems related. Whether the demonstration is being made in a prototype or a certified aircraft, the maintenance configuration management documentation must be up to date. No matter what the priority of the flight, if the aircraft is suspected of being unserviceable, or even if the documentation is not complete and up to date, there is no display flight, no matter how important it is for the Company to make the sale or for the Airshow Organiser to entertain the crowds.

The ramifications of having an accident during a display flight and the Accident Investigation Board finding that the aircraft was technically unsound or that the latest configuration standard had not yet been implemented, is too unbearable to contemplate. Accident Investigation Boards worldwide have a habit of digging out a lot of unrelated "dirt" that may not even be relevant to the accident but can, and will be used to portray unprofessional conduct by the Company, the pilot, or the Airshow Organiser from which rehabilitation is nearly impossible.

The 26 June 1988 Mulhouse-Habsheim demonstration flight accident of the newly delivered, Air France Airbus A320-100 left many questions unanswered. The official investigation concluded that the pilot had allowed the aircraft to descend through 100 feet at too slow an airspeed and at maximum angle of attack and was late in applying go-around power. Mr. Asseline, a former Air France pilot, was sentenced to ten months in jail by an appeal's court for manslaughter, but always maintained that the flight data used by investigators and displayed at the trial, was a fabrication. The crew, and Air France maintenance officials, were also all sentenced to probation for manslaughter.

Interestingly enough, no fewer than fifty-two provisional flight notices were subsequently published by Airbus Industry between April 1988 and April 1989. Two Operational Engineering Bulletins (OEB) OEBs subsequently published were particularly interesting. OEB 19/1 (May 1988) - Engine Acceleration Deficiency at Low Altitude and OEB 06/2 (May 1988) - Baro-Setting

Cross Check. After the Habsheim accident, the engines were subsequently modified (OEB 19/2, August 1988).

These OEBs were apparently sent to Air France but they had not been handed down to the pilots. In fact, both the engine and the altimetric systems were modified after the crash, which implies that they possibly did not function correctly at that time, but Airbus Industry was not held responsible by the French Courts, the responsibility was placed on the pilots and the airshow organizers. In today's litigious society, it is imperative to ensure that the aircraft is serviceable and that all modifications and manufacturer's advisories have been implemented and documented prior to the display flight. The alternative is a lonely and unfriendly survival act by the display pilot.

"Train for a safe programme and stick to it carefully. The big danger in airshow is emulation. You take a big chance changing anything during the show. Even on a well-known aircraft on which a pilot has a lot of experience, it is better to avoid any hazardous condition during the show. If a good show is impressive, it is not only by way of suspense. Spectators appreciate good execution of manoeuvres, not necessarily difficult, but done with evident ease and elegance. In the crowd watching our performance there are rather few technicians, pilots or connoisseurs, but rather a great deal of enthusiastic people not familiar with flight though in love with aviation. Do not try to astonish all of them, it is too difficult to succeed". (J. Coreau – Avions Marcel Dassault)

TIMING

Timing is extremely important at all airshows, but it is even more important at international airshows in which a dynamic, continuous flying programme has been scheduled. The specific demonstration sequence's duration will vary as a function of the occasion and the audience. Displays at international airshows will typically encompass the total spectrum of spectatorship; from aviation specialist to weekend aviation enthusiast and the display is usually limited to between six to eight minutes for single aircraft displays, increasing to between 10 and 15 minutes for formation displays. The rule of thumb, however, is not to make the show too long for fear of boring the spectators, it is better to leave them 'hungry for more'.

Commercial product demonstrat-ions to prospective customers are on the other hand, usually not time limited but will focus on the company-determined strategy in demonstrating all the potential 'selling points' of the aircraft. Commercial product demonstration flights are typically fifteen to twenty minutes long, enabling the test pilot to demonstrate substantially more of the aircraft's features. Since the sales demonstration flight is usually in competition with another aircraft, it can be hazardous trying to eek out that last bit of performance in attempting to display the enhancing features of the aircraft. An example that immediately comes to mind is the multiple rolls by the S-67 prototype Blackhawk at Farnborough 1974, the helicopter started the sequence too low and hit the ground on exit from the last of two rolls. The 'Blackhawk', painted in desert camouflage, was reportedly under consideration as a possible acquisition for the Israeli Air Force – could it be that the 'competition' could have induced the display pilot to extend the number of rolls from one to two?

The Airshow Organisers and Display Safety Committee take a dim view of display pilots not complying with scheduled time slots. There will be pilots anxiously waiting in the holding area or on the runway holding point for their call from ATC to enter the display arena, and unscheduled delays or extending the display, could result in disqualification or eviction from the show programme. Rule of thumb typically allows a scatter band of ±1 minute. On the dynamics side of course, the effect of density altitude must be considered since it could significantly affect the duration of the show because the pilot has to coast through transition manoeuvres and extend the show to manage the necessary energy requirements for each manoeuvre.

CARRIAGE OF PASSENGERS

The very idea that display pilots would be prepared to take passengers on a low-level aerobatic display flight just beggars belief. Yet analysis of the random airshow accidents in Chapter 3 revealed that forty-nine passengers were killed and fifty-two injured. The major contribution to passenger statistics was the 1988 Mulhouse-Habsheim Airbus A-320 crash in the approach configuration that resulted in three fatalities and fifty passengers injured out of a total of 136 on-board. Other accidents that contributed to the airshow accident statistics include the two enthusiastic aviation photographers from the UK who were killed in the crash of the sole airworthy B-26 Marauder during a display practice at Odessa, Texas in 1995 while a passenger was killed in the Wirraway loss of control accident at Nowra, Australia (1999). In an in-flight structural failure, a newly married bride was killed in a Fouga Magister at Deke Slayton in Wisconsin June 2001 as a plane ride gift and a former astronaut died in the Bf-108 airshow accident at Berlin Johannistal Germany in 1995. Fortunately for the passengers in the Britten Norman Trislander crash at Lanseria, South Africa in 1977 and in the De Havilland Buffalo crash at Farnborough in 1984, were fortunately only injured.

No passengers should be carried on a display flight and unless in current practice with the aircraft type and serving in the role as a crewmember of the aircraft, the minimum number of crew should be carried. So often in commercial demonstration flights, the potential customer is treated as a VIP and management go to extraordinary lengths to make the customer feel 'comfortable', promising the customer the 'world' and flights for the 'Buyer's team members,' all in effort to promote the sale. The carriage of passengers on flight-test demonstrati-ons or any airshow displays are generally prohibited by most Flying Control Committees, air forces and many Companies for very good reasons. Private owners of aircraft and those operating at non-regulated airshows, however, are not normally tied down by such regulations and have been known to take along the technical support staff or a friend, with disastrous results.

The passenger may obstruct the flight controls, become airsick or distract the attention of the pilot, inhibiting the display and possibly giving the display pilot or even the aircraft, a poor reputation. A passenger could also double the number of casualties in the event of a crash and then of course there are the legislative ramifications and insurance liabilities resulting from injury or death of the passenger. Worldwide, airshow Display Flying Committees have long recognised that the airshow arena is a hazardous area for the pilot and passengers alike – it is sheer folly to allow a passenger onto an airshow display flight.

In terms of litigation, this is obviously not usually an issue within military circles since military personnel would normally have the necessary authority and insurance cover. However, in modern regulatory society, any proof of negligence would most definitely provide the basis for claims against the Company, the Service or even the display pilot. The prudent rule of thumb remains, no passengers should be allowed to participate in flight demonstrations.

FUEL ALLOWANCE CONSIDERATIONS

For some displays, especially in the earlier generation aircraft, in an effort to extract the maximum performance from the aircraft by increasing the thrust-to-weight ratio, fuel was usually downloaded to the minimum required, leaving no contingency fuel for emergencies such as undercarriage failure to extend, electrical or communications failure, etc. The practice of under-fuelling cuts the options available to the display pilot in the event of an emergency and could be very embarrassing for the display pilot, air force or Manufacturer seen to be taking shortcuts in safety to impress the spectators or potential customers. The pressure induced on the pilot knowing that there is insufficient fuel to handle an emergency could make for a 'rushed' display with the pilot focussed on fuel state instead of the actual display flight. Never make the mistake of taking on minimum fuel for show weight – this could turn out to be an extremely embarrassing and costly error!

The fuel allowance must not only cater for the duration of the display, but should make allowance for contingencies and emergencies. At an international airshow for example, the rule of thumb for minimum fuel is to allow for 20 minutes at idle power, 5 minutes at military power, show fuel and then in some cases, diversion fuel to an alternate airfield for either a VFR or an IFR approach. At an airfield with only a single runway, the call for a diversion could typically arise due to an on-runway accident obstructing the runway for use by other aircraft, however, most single runway airfields usually have a parallel taxiway that could be used for landing in an emergency. Fuel allowances for display and demonstration flying are subject to the same criteria as for any general or military aviation flight and remains a critical planning consideration for every display flight. Engine cuts from fuel exhaustion at an airshow or customer demonstration flight could certainly ring in the end of the career of most display pilots.

WEATHER CONSIDERATIONS

For aviation accidents in general and airshow accidents in particular, weather will always contribute a certain percentage to accident causal factors, typically in the form of density altitude, cloud base, visibility, crosswinds and wake turbulence, to list just a few. In the sample case of airshow accidents analysed in Chapter 3, however, Medium's direct contribution to display accidents was only 4%, which was considered to be mainly due to the majority of pilots recognizing the folly of conducting low-level aerobatics in adverse weather. Those not converting to the bad weather sequence in the belief that they can 'fit the show in' below the weather, make up the 4%. (Refer Chapter 3 for detailed analysis.)

Considering that demonstration flying is essentially a VFR exercise, the rationale and persistence of display pilots in flying dynamic manoeuvres at airshows in adverse weather, is difficult to understand. Maybe it's that old 'testosterone' problem or a requirement to impress peers with the 'can do' attitude. How far to 'press' before calling it a day, well, there's a fine line there. The existence of a practiced 'bad-weather' sequence in any display repertoire is thus essential to reduce weather–related accident categories. After 'Plan B', the bad-weather sequence, there is no other plan other than display cancellation, whether or not the Show Organisers like it or not. Rather a cancelled airshow than the downstream adverse affects on future airshows, litigation and insurance cost increases resulting from an airshow accident.

A 'low' or 'flat' option B should be planned and practiced to allow for low cloud conditions and since lower visibility may be associated with low ceiling conditions, the alternate programme may need to be flown at lower airspeeds. Obviously, the reduced ceiling sequence show must be flown to keep the aircraft within easy sight of the spectators and can in many cases appear to be, aesthetically, more impressive. Although it may at first instance appear to be less interesting, the 'flat show', usually being composed of easier and less aggressive manoeuvres flown at lower speeds, is often more appealing to the airshow spectators since they get to appreciate the relative closeness of the aircraft. The low ceiling sequence will be designed to emphasise the horizontal performance capabilities whilst avoiding the vertical. It is useful to transform all vertical loops or Immelmans into horizontal turns, either complete, or inverted through a Derry turn. It may also be handy to plan and practice for the contingency of flying a reverse, mirror image, take-off manoeuvre to set-up the display routine should prevailing wind conditions force the issue.

Density altitude remains one of the most critical considerations often overlooked in terms of weather conditions. The display pilot is often so focussed on whether a good or bad weather sequence will be flown, that it is easy to forget that some of the most beautifully hot cloudless days found during the airshow season bring with them the unseen threat of density altitude. It is critical to be aware of the effects of ambient temperature on the thrust output of the engine and also the IAS/TAS relationship – the higher the temperature, the higher the density altitude and the higher the TAS for a given IAS. It is essential that the total energy at the respective 'gates' of the display routine and also the vertical margins, cater for the range of anticipated hot and high altitude conditions.

Formation teams by virtue of their lower manoeuvrability usually fly wider shows than singletons or synchronised pairs and are also more adversely affected by the weather. The *Red Arrows* actually have three different categories of displays and operating with its particularly fickle weather and cluttered airspace, they get to display categories each season. Many of the display manoeuvres accommodate the local weather conditions but some have to be completely changed or avoided.

The three different displays are the Full Display, the Rolling Display and the Flat Display. The Full Display, although not longer in duration or more involved than the other two, is the favourite of both the team and the public, enabling maximum demonstration of the aircraft and the team's capabilities. All formations, including the Queen's Golden Jubilee and the Jubilee Split can be looped using the full vertical extent of the reserved airspace.

The Rolling Display is used when the cloudbase is below 5,500 ft and since safety margins are reduced in these conditions, they will fly a rolling display which, instead of going fully into the vertical to loop the formation, the Team will instead 'roll' the formation. Lastly, the Flat Display will normally be performed if the cloud base is below 2,500 feet; all manoeuvres are performed in the horizontal, leaving out the vertical completely.

Once chosen as a display pilot, unless unbelievably lucky, the pilot will certainly end up displaying in weather that is right on the aircraft and the pilot's own personal limits. Whilst the regulations and the Display Director should prevent pilots from exceeding the limits, peer pressure and organiser expectations are likely to ensure that pilot's do display right up to the regulated limits; it is up to the display pilot and the training supervisor to ensure that personal capabilities can cope with the entire spectrum of anticipated weather conditions. Furthermore, it's odds-on that a pilot will end up, at least once, flying in unsuitable conditions due to bad luck, bad judgement, or poor weather forecasting and reporting.

An RAF Lightning display pilot and subsequent supervisor for a Hawk display work-up, Group Captain John Fynes, thought it worthwhile to discuss some of the pitfalls and lessons learnt during his display career due to inadequate preparation for, or consideration of weather, on a display. "My first public display was in front of 60,000 people in an on-crowd wind of 38 kts in a 200 foot cloud base and pouring rain. Although I was desperately nervous of what my peer group of display pilots would think of my display as much as the public, I had no real concerns about the weather because I had trained for it".

"My supervisor, an extremely tough Station Commander, had insisted that I train in every marginal yet legal weather condition. On one occasion he had even called me in from home prior to night flying to make me practice in a 40 kts on-crowd wind! I recall in later years as a Squadron Leader arguing with a Wing Commander who would not let the Hawk display pilot practice in any really difficult weather conditions during his work-up. I know that the display pilot had some particularly hairy occasions during his season that he did not feel adequately prepared for".

"But what about the unexpected? I scared myself several times during my season, the closest call to becoming an accident being weather related. Instead of taking the sensible and easier option, I allowed myself to be put into a situation that had little solution except luck. It also happened to be at the biggest display of the year, at Royal International Air Tattoo, RAF Fairford. One of the most impressive aspects of the Lightning display was it's "rotation" take-off, a manoeuvre that was incredible to fly as well as to watch. In essence, you held the aircraft as low as you dared whilst turning sharply away from crowd through 45º and accelerated to 260kts. At this point you snatched the control column to your stomach and then progressively pushed forward. The aircraft rotated around its tail, and, if you judged the push correctly, adopted a ballistic 60° - 70° nose-up climb".

"If you left the push too late, you risked falling on your back, or worse, tail-sliding into the ground. Several Lightnings had been lost performing this manoeuvre and only display pilots were still allowed to do it. Fun, or what? However, once pointing upwards you could not physically stop the climb by over-banking, until about 1,200 feet when with little speed remaining, you gently entered the next manoeuvre or continued a steep climb whilst the nose dropped, not really a good idea if in cloud. I therefore needed a minimum cloud base of 1,200 feet to fly this take-off manoeuvre. At Fairford the cloud base was varying between 800 feet (flat show limit) and 2,500 feet with drizzle, making it impossible to judge from the ground".

"Although intending to go for my safe boring take-off, the aircraft getting airborne ahead of me to depart to the holding area agreed to pass on the height of the cloud base, thus allowing me to change to a "rotation take-off" if suitable. I was waiting to take-off and got the call "go for it". So I did. I went into cloud at 600 feet with 70° nose up! I came back out of it pointing the wrong way, 50 kts slow, and at the wrong place to flow into my display.

The only good news was that I had come out at a place with a useable 800 feet cloud base. The adrenalin was flowing, I was furious at my 'mate' in the departing Phantom and my public needed me. Needless to say, the crowd got an unrehearsed next two minutes as the reheat never stopped and I roared around making lots of noise until I achieved a known spot in my display and enough speed. Although I received a couple of "that looked sporty" comments and a significantly raised eyebrow from the ex-Lightning pilot on the safety committee later in the bar, nobody seemed to realise how close Fairford got to practising it's disaster plan".

The lessons? Many! "I had never even considered what to do if I went into cloud on my "rotation take-off". Once a reasonable weather decision is made, don't change it. Never trust a Phantom pilot! He later told me that he knew the weather was below my limits but was worried that if he said the weather was that bad, the display organiser would not let him display after me! Only the Lightning had enough power and performance to have let me get away with it. The moral of the story? Think about the weather, when the work-up is going well enough, practice in the worst weather you can find. Don't fly a weather-dependant manoeuvre unless the weather is good enough".

Within the definition of weather, there is the element of the wind which can cause significant problems to the pilot in maintain show centre and also the showline. The lower the aircraft's airspeed, the greater the adverse affect of drift – the higher the pilot's workload and wind can in itself be a major contributor to pilot disorientation. Take for example the case of the pilot of an British Army Corps Beaver who was tasked as part of the air display for the RNAS Culdrose Air Day on 27 July 1983 to give a single aircraft display to show the capability of the beaver aircraft, a light single engined six-seat liaison aircraft. The aircraft was climbed to 100 ft before the display sequence was to start with a figure of eight manoeuvre in front of the crowd line. During the second 360° turn to the left, the port wing struck the ground and the aircraft crashed clear of the crowd. All emergency services were on the scene within one minute but the pilot was confirmed dead shortly after being pulled clear of the wreckage.

The accident investigation board found that the existing meteorological conditions were a major factor in the cause of the accident. At the time of the crash, the wind was gusting up to 27 kts at right angles to the centre of the display axis which itself was parallel with the crowd line. This caused the aircraft to be blown towards the crowd line. As the pilot was approaching his second turn, he was flying a gradual slope, which many not have been apparent to him. The combination of wind and slope could possibly having given the pilot an impression of considerable speed over the ground when approaching the crowd line. He may have instinctively then have reduced the airspeed to a state where his safety margin above stalling speed was slight. The pilot was very experienced with over 6,000 flying hours and the display, which he had performed on previous occasions, was within his capabilities. (David Oliver)

BRIEFINGS

Before, and on show day, it is incumbent on the organisers, be they military or even a civilian aircraft Company, to present a briefing to all participants regarding essential safety critical considerations. All too often at smaller airshows, participants make a habit of arriving late, hurriedly collecting the information later from the ground liaison/safety officer. The plea often heard from display pilots at the smaller airshows is for a telephonic briefing; it may be more convenient but it leaves the Co-ordinator of the Flying Control Committee open to extreme criticism and even possible litigation in the event of an accident. The rule of thumb in all cases must be: “no formal briefing – no show”, there can be no exceptions - attendance by all participants is mandatory.

More particularly, the briefing should include the weather forecast for both the show location as well as the diversion fields. Abort criteria for sequence critical items such as cloud base, visibility and wind conditions must be clearly defined and once such criteria have been reached, it is then a clear-cut decision, “if there is any doubt, there is no doubt” – move to the bad weather or ‘flat’ sequence. In addition, any aspects that could increase the possibility of disorientation must be considered, including wind shear and turbulence. Obviously, the radio frequencies, primary and standby, ejection areas, forced landing areas and the overall programme schedule must be addressed. Finally, ‘Plan B’ - in the event of any contingencies affecting the programme e.g. crashes on and off the airfield, emergencies resulting from aircraft malfunctions and blocking of the active runway, must be briefed, amongst others.

FLYING THE DISPLAY

Display day is also ‘adrenalin day’, the day the plan and many hours of practice comes together. In similar disposition with top international sporting events, the mental preparation and focus on performing at an international event or even a local airshow, can unleash a vast amount of adrenalin and nervousness. Nervousness itself is normal and to be expected, the late John Derry, in a lecture to the Royal Aeronautical Society in 1951 remarked that: “Contrary to popular opinion, he must possess a good fear. Fear is the pilot’s governor”.

Ask any display pilot, whether novice or ‘old hand’, each one experiences nervousness, ‘butterflies in the stomach’, as the saying goes. The novice display pilot may even question whether or not he is the right person to be doing the display. Questions of weather will be foremost in the mind of the display pilot, atmospheric conditions such as visibility, cloudbase even spectator mood – very similar to theatre performers that try to sense the mood of the audience. It is important to be focussed from as early as possible on the task at hand, therefore, ensure that the technical support staff are ‘on the line’ timeously with a serviceable aircraft - try to get airborne on time and allow some time for ‘loosening-up exercises’.

Surely one of the most healthy bits of advice that any reputable display pilot will provide is that once the display has commenced, the plan must be implemented, “fly the show you practiced” without improvisation or any impromptu manoeuvres or sequence changes. The display routine has been designed to be flown within known boundaries, there is nothing to be gained by introducing any changes unless safety of flight is compromised. If at any stage during the display there is any doubt, ‘there is no doubt’ i.e. the decision to abort the show if anything goes wrong is a pre-planned decision. The display pilot must know the abort criteria, make the decision on the ground that should such criteria occur, the sequence will be terminated via a practiced procedure.

If, for whatever reason the show routine must be compressed, it is advisable to rather eliminate a manoeuvre than to take short cuts and attempt to ‘squeeze in’ the whole sequence.

In any event, if ever such a situation should prevail, it should immediately trigger a warning flag to the pilot for increased vigilance since the pilot is now in a most vulnerable zone since the cues and the "energy gates" might be out of synchronisation with the plan. An unpractised interruption of the practiced subconscious may not be time synchronised with the cognitive mind control with disastrous consequences. Russia's aerospace industry tried to lay the blame for the Tu-144 crash at Paris in 1973 and the Su-30MK, also at Paris Airshow but in 1996, at the door of the airshow organisers. In both cases, the demonstration routines had been shortened by a few minutes

In Howard Moon's book, he concluded that the root cause of the accident was actually the rivalry between the Concorde and the Tu-144 and that a contributory cause was that the French cut back on the carefully rehearsed Soviet display flight time at the last minute and extended the demonstration flight time of the Concorde. At one stage of the display, the crew on the '144 were forced to improvise a landing and apparently tried to land on the wrong runway. Airshow Commissioner, General Edmond Marchegay lauded the pilots for recovering the aircraft and avoiding a catastrophe. However, he noted that flight routines are commonly changed at the last minute, and that the Russian crew had agreed to the changes requested. "If they agreed to the changes, that meant they thought they posed no particular problem." The modified routine had already been flown three times before the mishap and had been approved by the Flying Control Committee.

Following the Su-30 MK crash, at a press briefing the following day, Sukhoi general director, Mikhail Simonov, said preliminary analysis showed no technical failure. He made no mention of "pilot error," although he had previously used that term to describe the probable cause of the accident. Simonov attributed the mishap to a late decision by show organizers to shorten the display from eight to six minutes, forcing the pilots to cut several manoeuvres and redesign the sequence. Sukhoi officials claimed that the changes had made it necessary to modify the initial flight parameters in a number of manoeuvres, causing the duration of recoveries to be lengthened, with a loss of altitude and change in exit direction that were "difficult to predict." The subsequent apology by the test pilot in a Reuters report on 13 June 99, the pilot of the Sukhoi-30 apologised saying he accepted the blame after attempting an ambitious aerial manoeuvre that must have been rather embarrassing to come to terms with. "Sorry, I did one too many revolutions in a flat corkscrew and I couldn't pull her out. I didn't have the altitude to get the plane out of the manoeuvre," Averyanov was quoted as saying. Display sequence improvisation in any form is totally unacceptable

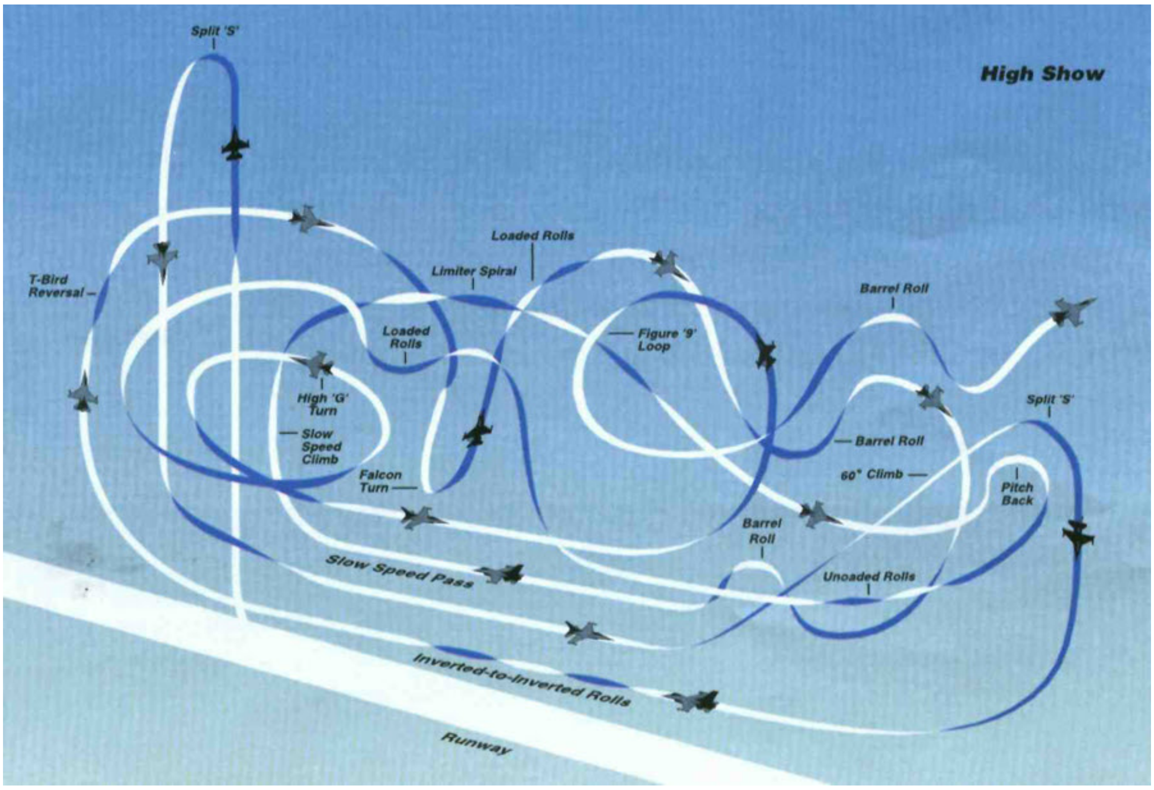
In terms of techniques, crosswind compensation should be applied during the vertical ascent since the wind has more effect on the aircraft when the aircraft is slow, thereby having more time to affect the aircraft. Manoeuvring back onto the show line, if required, is then applied on the descent when the show line is more easily visible to the pilot than on the ascent. Furthermore, to get the shape of the loop rounder for the spectator on the ground, the entry to the loop should, if possible, be into wind. The top of the loop will appear slightly flatter as the aircraft's ground speed increases at the top of the loop thereby effectively reducing the "egg shape". The headwind effectively stret-ches the downward acceleration leg thus presenting a rounder shape.

Precision and timing with attention to detail are the key success factors of a safe demonstration flight. Theoretically, and in ideal conditions, a display pilot should be capable of producing a precision display on instruments alone if there was no crosswind. The display pilot should be capable of not only demonstrating the aircraft but also handling the widest permutation of contingencies.

Only if you have personally competed in a fly-off or flown at an international airshow will you understand the pressures on the display pilot – similar to the 'million dollar putt to win the US Open Golf Championship'. At international commercial airshows particularly, the competition between pilots, especially those hoping to impress a potential buyer is significant;

the pressure on the display pilot is high since not only is it important to impress the potential buyer, but the competition's test and demonstration pilots who will be 'critiquing' each and every moment of the display. A 'brilliant' show can be worth millions of dollars in successful sales and as such, show business people will understand the concept of a brilliant performance better than most display pilots.

The 2002 Farnborough International Lockheed Martin F-16 demonstration flight was flown by Troy Pennington, the senior experimental test and demonstration pilot. The display was designed to best show off the enhancing qualities of the F-16 by flying really 'tight-and-in-sight' as the best points were demonstrated to potential customers. The emphasis was focussed on three primary performance parameters, thrust-to-weight ratio, agility and the ability to sustain energy – all extremely valuable components of a fighter aircraft's capability and



Lockheed Martin's F-16 Display Sequence flown by Troy Pennington at Farnborough 2002. (Aviation Week ShowNews)

survivability in the modern threat environment. Flying with two-thirds internal fuel at a representative combat weight of 24,000 lbs and propulsion supplied by the 29,000 lb thrust GE 119 engine, the prevailing T/W ratio of approximately 1.2:1 enabled the F-16 to sustain 9g all the way around the turn and actually accelerate in the turn thereby really demonstrating the energy sustainment potential.

The display began with a short takeoff roll of 1,000 ft converting to an immediate vertical climb that topped out at 3,000 ft into a Split-S. Pulling over at maximum AOA right on the flight control limiter utilising the computerised fly-by-wire flight control systems, the pilot did not have to worry about overshooting or getting into trouble with AOA. Indeed, he relied on the on the limiter a lot during the show, demonstrating how a combat pilot could fly the F-16 'almost with reckless abandon' and still not get into trouble. From the Split-S, the F-16 demonstrated its agility in roll with a quick succession of rolls, first to inverted, then to the right, back to the left, and to the right again to achieve erect flight in demonstrating the smoothness and precision of the FCS.

One noteworthy manoeuvre was the ‘Falcon Turn’, a trademark of the F-16, combining a hard turn with a very fast pull-up and re-instituting the hard turn again. This was followed by a ‘g-loaded roll’ at the top of the manoeuvre right on AOA limiter but at an airspeed that provided an impressive roll rate, resembling a ‘corkscrew roll’. The flight control limiters also have their limits though and do not protect the airframe from overstress in asymmetric rolling manoeuvres such as the ‘loaded-roll’. The requirement is to be at high ‘g’ and high AOA to make it dramatic, yet the airspeed must be low enough not to exceed the structural limits. Another impressive aspect to the F-16 display was the dramatic entry to the slow-flight pass from a slow barrel roll. This roll brought the fighter to Farnborough’s 600 ft minimum display altitude and was certainly attention getting, incorporating a fairly aggressive vertical manoeuvre that until arrested, appeared to the spectators to be headed for a ‘hole in the ground’.

The slow pass was followed by a vertical climb to 2,000 ft and a pull-over into the ‘limiter spiral’, which again demonstrated the FCS protection of the aircraft from extreme control limits. The aircraft was pulled down with full aft stick and once the nose approached the horizon, the stick was moved into one corner which maintained the AOA and also initiated the roll. It initially looked as if the aircraft had departed controlled flight, but in fact, it was just doing a maximum performance roll and turn which resulted in a fairly tight spiral going downhill. Then a pitch back, a couple of unloaded and loaded rolls leading into the hard work of the 9g turn through 360º.

Demonstrating the latest generation fighters has become physically a lot more challenging. In earlier third generation fighters, the pilot just put the throttle in afterburner and left it there for the most part of the routine, particularly since the energy budget for high-g manoeuvres was limited. But with the higher thrust engines and T/W>1, pilots have had to hone not only their energy management skills but also their physical stamina and conditioning. Cold, sea-level conditions are particularly strenuous since the lower density altitudes make the engine noticeably more powerful.

Unnecessary and subconscious pressure is often placed on display pilots by the perceptions and expectations that the display pilot will demonstrate his personal skills, not necessarily the fine performance or handling qualities of the display aircraft. It is not necessary for the pilot to prove just how good he is; it is pointless pushing the edge of the boundaries purely to demonstrate just how good you are as a display pilot. Although it is sometimes difficult to believe, it is unnecessary to break regulations in an effort to meet the supposed ‘expectations’ of the spectators.

DISPLAYING HELICOPTERS/VSTOL

Flight displays with helicopters do not necessarily present the same dynamicism or fascination for spectators as for high performance fighters. It is unfair in fact, to compare a fixed wing and a rotary wing display since they are completely different categories and classes of air vehicles. However, helicopters do hold a fascination for a significant proportion of the aviation spectator population and the performance and agility of the helicopter has increased to such an extent that the display put on by the modern helicopter can potentially have as much aesthetic appeal as that of the most modern fighter. Then there is always also the ‘romantic’ that continues to associate helicopter aviation in all its forms with the classical ‘magnificent men in their flying machines’.

The VSTOL fighter finds itself placed between the fighter and the helicopter, providing spectators with a compromise, the low speed manoeuvring capability of the helicopter combined with the high speed agility and performance of a fighter, making it possible to create an eminently watchable airshow routine. The P.1127 Kestrel first flew in 1960 and from the outset fascinated not only the pilots, but also the spectators. Since those early days, VSTOL aircraft, and in particular the Harrier, have proved beyond doubt that the future of VSTOL aircraft, more specifically the Joint Strike Fighter, is assured in terms of spectator appeal. VSTOL brought with it a totally new dimension in display flying – the principle of vectored thrust had arrived not only to stay, but also to prove that the revolutionary capabilities of VSTOL could compete with contemporary combat aircraft in terms of payload and manoeuvrability.

The display environment for the VSTOL/helicopter may vary considerably, from International Air Displays to small local Open Day events, from large unrestricted arena's and vast audiences and open spaces, to small, restricted operational demonstration areas; they are all different, all difficult. This is where ingenuity, skill and not a little deception, are all part of the game. Paris may be quite different from Farnborough, Farnborough quite different from any other place, but VSTOL remains a 'showstopper' for the public. "The ability to transition a heavy, high-speed jet into a nimble, hovering bird never ceases to amaze the spectators – the noise of course, is especially loud". (Duncan Simpson, former Hawkers Test and Demonstration Pilot)

Most of the general aspects of displaying VSTOL aircraft, including the art of high-speed aerobatics, are essentially similar to the conventional take-off and landing fighter jets. Suffice it to say, the Harrier has an impressive manoeuvre capability and is well endowed with a thrust-to-weight ratio in excess of one. The composition, planning and positioning of the aircraft therefore, follows the well-known, contemporary state of the art. However, on every Harrier display, the take-off and landing sequences tend to be the most demanding and invariably involve flying very close to the performance and handling limits.

An unusual and unique ability of sequence design for VSTOL and helicopters, is the capability of co-ordinating two air vehicles because of the wide low speed activity range of either or both the aircraft involved. Short take-offs, vertical take-offs, transitions – shallow and steep – high speed runs, aerobatics, thrust vectoring in conventional flight, pad landings, manoeuvring at the hover, and all that possible in the space of six minutes! Noise and spectacle yes, but dare one hope that the informed observer had understood the finer points, the performance, loads, the possibilities, the potential? On many occasions spectators have been sceptical of the performance or misunderstood the manoeuvres being demonstrated by VSTOL aircraft. At Farnborough in 1974 the Harrier was landed on a 50 ft mat with 5 x 280 kg bombs, and took off again – in those days an unbelievable feat – but how many of the spectators actually understood the achievement. The latest versions of Harrier, Sea Harrier the Marine Corps AV-8B and in future, the Joint Strike Fighter will all have significantly increased thrust margins but even then, a high level of skill will still be required, particularly in high-density altitude conditions where thrust available is severely degraded.

The agility and manoeuvrability of the Harrier manifested in amazing hovering, sideways and rearwards flight, remains a 'showstopper' wherever and whenever it appears. The famous 'bow' – the spectators favourite? (Reproduced by kind courtesy of Airshow magazine 2002, Key Publishing)

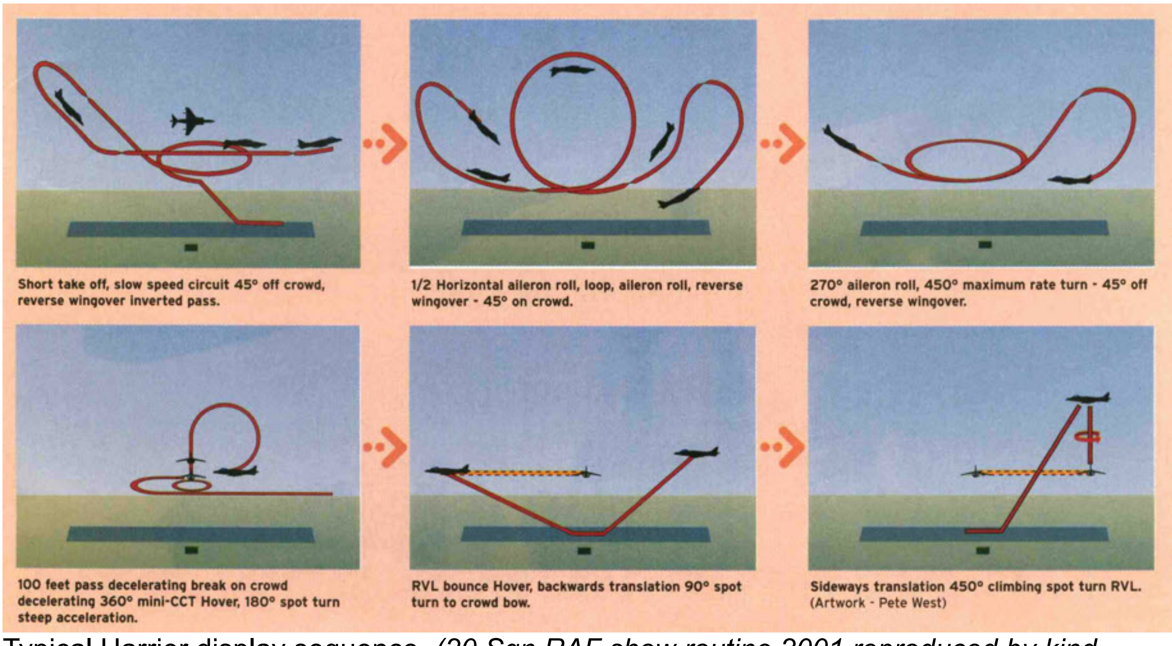
VSTOL brings an added dimension to the display circuit, possessing the agility of a high speed fighter and the low-speed manoeuvring capabilities of a helicopter and it may thus be said that in displaying a VSTOL aircraft, 'groundsmanship' is just as important as airmanship. The display pilot will spend much time in surveying and analysing, considering the possibilities of the exercise not quite going as planned. Aspects that must be considered include approaches to and exits from the site, escape routes if difficulties should arise and the surface of the landing area and its surrounds. All these aspects emphasise the importance of correct positioning of the aircraft with the primary objective being the safety of the spectators.

Because of the inherent limitations of hovering flight, careful performance planning is absolutely essential based on accurate temperature and pressure information since performance margins will depend on the loads to be carried and on the demonstration environment. For instance, a pad landing in the trees will require more margin than a standard approach and landing on an open space. Short-term limits and water injection in the engine must be carefully calculated and monitored.

An RAF Harrier GR7 of 20 Squadron RAF Wittering crashed into the sea at the Lowestoft (UK) annual airshow in August 2002. Nearing the end of the display sequence in the hover and preparing for the 'bow' in front of the 40,000-strong crowd, the Harrier lost power and descended rapidly from the hover. At about 50 feet above sea level the pilot ejected. The Harrier landed heavily on the sea surface and floated for several seconds before sinking and the pilot's chute opened just in time to complete one pendulum before he landed on the sinking Harrier, injuring an ankle. Had the accident occurred directly over land and the aircraft exploded, the pilot would certainly have landed in the post impact fireball.

Similarly, in the case of the prototype Harrier crash at Paris Airshow in 1963, uncommanded nozzle operation in the hover resulted in the aircraft dropping out of the hover, but fortunately from a few metres only. Within the display environment, engine malfunction within the hovering flight phase poses the single largest threat to the pilot since not only is the engine operating at very high capacity, but the survivability of the pilot following an ejection from the hover could in all likelihood result in a fatal accident.

VSTOL commercial sales demonstration flights would obviously shift the focus away from conventional display flying, to emphasise mission relation exercises and demonstrations.



Typical Harrier display sequence. *(20 Sqn RAF show routine 2001 reproduced by kind courtesy of Airshow Magazine 2002, Key Publishing)*

In particular, operations out of confined spaces such as natural habitats of rough woodland, grassland and narrow tracks – a 50 ft pad within forest scrub, a possible typical operational landing pad. Demonstrating vertical entry, refuel, rearm and departure from the 50 ft mat is extremely impressive and make no mistake, is a demanding task. A short take-off through a narrow gap in the trees, a return at 600 KTAS through the same gap, maximum rate turns and aerobatics, a tight decelerating transition and a vertical landing on the pad – all manoeuvres that require extensive skill and practice but certainly demonstrate the huge military potential of the VSTOL concept.

Another critical consideration in the planning of VSTOL and helicopter display flying arises from the fact that the aircraft can operate from all sorts of possible locations such as battle areas, airstrips, ships, golf courses and even outside of museums in built-up areas. It will be appreciated that these types of demonstrations place a tremendous responsibility on the pilot and the display organizer, operating in close proximity to spectators and public facilities in some cases. Such operating environments present several hazards and comprehensive planning is required in collaboration with local Town Councils or Municipalities. The Safety and Medevac plan being particularly challenging in such cases.

The advantages of such high manoeuvrability in an aircraft implies that weather is in some respects less inhibiting for VSTOL and helicopter aircraft than for conventional fighters. Even in low cloud or poor visibility conditions, it is still possible to demonstrate some aspect of the aircraft, whether it be jetborne or semi-jetborne. It avoids disappointment for the crowds and provided the visibility is greater than 2,000 metres and cloud base not below 200 ft, a restricted ‘flat’ show is possible. In fact, the Harrier can for instance, fly one of four displays, depending on the cloud base. A ‘full’ display can be performed if the cloud base is higher than 5,000 feet, a ‘rolling’ display when the cloud base is between 5,000 feet and 1,500 feet, a ‘flat’ display with a cloud base below 1,000 feet and a ‘V/STOL’ display if the cloud base is below 300 feet (90 m). Such versatility provides the display organiser with a ‘ace’ in the event that weather prohibits the utilisation of conventional fixed wing aircraft from displaying. It is clear that the VSTOL aircraft lends itself to the spectacular, including manoeuvres which are definitely not in the ‘old book of rules’. The VSTOL aircraft and latest generation helicopters bring a new and exciting dimension to aerial displays providing interesting permutations of manoeuvring capabilities.

A typical VTOL display routine used by 20 Sqn RAF during the 2001 airshow season, was a take-off followed by a slow-speed 410º circuit flown at less than 100 knots, immediately transitioning by accelerating away from the crowd in a 40º climb. From a reverse wingover, the Harrier passed in front of the spectators, inverted at 400 kts. The aircraft was then rolled upright for a half horizontal eight, finishing back at crowd centre where it fed into a loop. Upon completion of the loop, the Harrier followed with an aileron roll, reverse wingover, 270º aileron roll, 450º maximum rate turn and reverse wingover, all in order.

A fairly rapid 500 knots pass at 100 ft (30 m) led the aircraft into a 7-g break-away with nozzles lowered to decelerate rapidly. On returning to show centre, the Harrier flew a 360º mini-circuit at only 30 knots, then faced the audience head-on in a hover while consuming water for cooling at the same rate as fuel to keep the weight balanced by thrust alone. A 180º spot turn followed by a steep climb away from the crowd at slow speed, while rotating the nozzles rearwards during he manoeuvre, further demonstrated the aircraft’s unique flight characteristics. With nozzles lowered again, the Harrier descended in a steep spiral for a rolling vertical landing at show centre before transitioning into the hover. The Harrier then paused briefly during the hover before performing a backwards translation to the crowd centre, where it spot turned 90º to face the spectators and impress the crowd with the ‘bow’. One last sideways translation further amazed the spectators and then it’s the last hover, a 450º climbing spot turn before descending steeply for a rolling vertical landing at show centre completed a typical eight minute show.

A last word on flying the show. The hazards are real; the display pilot pursuing the conflicting requirements of displaying the maximum performance of the aircraft at low-level and very close to the thousands of spectators, imposes its own adrenalin. There is no room for non-compliance with safety regulations, the ultimate price to pay could be measured in terms of many lives – You can't afford it!

COMMERCIAL PRODUCT DEMONSTRATION FLIGHTS

Although by definition, different than Display Flying, Product Demonstration Flying is actually only really different in terms of the objectives of the display, which in turn could affect the routine. There is really only one cardinal difference between Demonstration Flying and Display Flying. In the commercially orientated flight test product demonstration, the focus is on exhibiting the aircraft's performance and handling qualities to the prospective customer, while in display flying, the emphasis is on the skills of the pilot in making the aircraft 'talk to the spectators'.

The primary aim of a flight demonstration is to promote the particular aircraft in support of the Company's marketing strategy. Complementary aims of such a demonstration are to enhance the Company or Service's reputation by the presentation of a safe, imaginative, sensible, competitive and professionally impressive display. The demonstration must transfer the positive and enhancing features of the aircraft to the spectators or prospective customers, while minimising the aircraft's shortcomings.

New product demonstration flights at domestic and international airshows are an essential component of the commercial marketing campaign of an aircraft's life cycle. These demonstration flights require the pilot to focus his efforts on flying a convincing display of the aircraft's capabilities at low altitude within the confined volume of the airshow box. Airshows typically encompass a variety of different specialized routines, ranging from formation aerobatics on the one hand, to barnstorming and pylon racing on the other. All this in order to satisfy the requirements of the spectators, whether they be fare-paying members of the public, or potential customers. The point is that the design of precision formation team performances and "barnstormer" demonstrations are based on very different technical concerns and demonstration objectives.

Precision formation teams demonstrate pilot training and formation air-work skills and the focus of these displays are extreme discipline and pilot skills. Barnstormers seek to thrill the crowd in ways that are uncharacteristic of a product demonstration. For example, extremely low altitude inverted flight to cut ribbons being held between two pylons on the ground, or record-breaking consecutive snap rolls, all designed to impress the thrill-seeker who is looking for a performance that keeps you on the "edge of your seat".

While these types of displays are intended to thrill and demonstrate the daring nature of flight, many of the manoeuvres are dependent upon pilot skill level and the pilot's willingness to accept risks based on his/her abilities and not so much the performance attributes of the aircraft. In contrast, product demons-trations are flown for the sole purpose of displaying to a discerning observer the aircraft's performance attributes and not merely the pilot's skill level. The bottom line is that to be effective, product demonstrations require the aircraft's unique performance traits to be displayed at low altitude before a discriminating and critical, potential customer.

As a result, product demonst-rations push the outer edges of the flight envelope in ways that formation teams and barnstormers never or rarely do. Pilot skill is obviously a factor in these displays; however, it is the aircraft's capabilities that are pushed to the limits and not necessarily the pilot's and it is precisely this that makes product demonstrations a dangerous and unforgiving flight arena. Sadly, many aircraft and pilots have been lost over the years during the development and execution of product demonstration performances.

The commercial demonstration flight can be a two-edged sword; the publicity and positive response to performing publicly at major airshows with the possibility of increasing sales, is often offset by introducing delays to the flight test programme. This may be difficult for programme managers to accept or even to accede to since their management directive is aimed at producing a product on schedule. Unfortunately, in most aircraft development programmes, demonstration flights and airshow performance are generally not necessarily scheduled and any unscheduled activity means more pressure later in the flight test programme with the possibility of incurring cost overruns. So, what guidelines should the commercial demonstration pilot consider in best exhibiting the air vehicle to a prospective customer? What are the requirements for the selection of demonstration pilots, what are the guidelines regarding the target audience? What are the demonstration pilot's responsibilities towards the Company? What are the responsibilities of management? What are the demonst-ration's pilot's responsibilities to the prospective Buyer's team and pilots, briefings and reporting?

Flight test demonstrations alone do not sell an aircraft, but they do serve as an invaluable adjunct to prospective customers to get a "first look" at the potential capability of an aircraft. Flight test demonstration, is as in all cases of exhibition flying, a hazardous aerospace activity that is not only important from the commercial viewpoint of "making the sale", but can be potentially dangerous, having killed several demonstration pilots over the years, including highly experienced test pilots.

The range of locations at which flight demonstrations could be presented, may range from the international exhibitions such as Farnborough International, ILA (Berlin) or Le Bourget (Paris Airshow), the Manufacturer's premises or even at military bases if the aircraft is already in Service and use is made of a fleet representative aircraft. Demonstrating an aircraft at the customer's premises is somewhat different than at home base and in most cases, more analogous to a public airshow with the main difference being that more time is generally available and safety regulations may be less restrictive without the large crowds of spectators. Also, the requirement to carry diversionary fuel may become superfluous since all other flying invariably ceases for the duration of the demonstration.

A vast amount of airshow pilot experience lies within the ranks of the Society of Experimental Test Pilots (SETP). In 1987 an Airshow Safety Committee was formed to research airshow experience and interview veteran SETP demonstration pilots with the intent of learning lessons from these survivors. Roy Martin, Frank Sanders, Joe Jordan and Bruce Peterson were instrumental in consolidating the available information into an SETP paper titled 'Airshow Execution' which was then presented at the 33rd SETP Symposium. In 1989, this committee, working under the guidelines of the SETP Constitution, Article II, Section 2, set about to gather pilots opinions, ideas, experiences and information to aid in the advancement of flight safety as it pertains to airshows and aerial demonstrations.

DEMONSTRATION SEQUENCE DESIGN PHILOSOPHY

A product demonstration profile requires the careful orchestration of specific manoeuvres and requires a thorough evaluation of the aircraft and its systems. Manoeuvre selection must be based on engineering analyses, flight simulation, and flight test evaluations. Both aircraft-unique manoeuvres and specific emergency recovery procedures may need to be developed. When done properly, the resulting airshow profile must be safe, repeatable, and demonstrate the aircraft's unique capabilities. The development of the BAE Systems Eurofighter and Boeing Company F/A-18E/F Super Hornet airshow demonstration profiles both used a disciplined "flight test" approach to ensure key elements were addressed – elements believed critical to a methodical and safe development of the airshow profile.

Comprehending the psychology that motivates us, both as flyers and observers at airshows is essential to fully understand the fundamental motivations for doing a show. Comprehending the thoughts and emotions of the observers needs to be truly understood if one is to design and fly a successful airshow sequence. Airshows that have failed in the past, were in many cases, caused by not understanding the philosophical question of what these pilots were trying to accomplish. Many airshow accidents can be linked, not by any numerical or technical common denominator, but by a common thread that points to an error in the fundamental misunderstanding of *what* the pilot's real objectives were for the mission.

In any large airshow there are basically four very distinct and separate disciplines that are on display. Military team demonstrations, high-performance aerobatics acts, Product demonstrations and historic flights. Each of these disciplines has a very pure and fundamental basis upon which they exist. Therefore, it is possible to further breakdown the very principles upon which each show should be designed.

Military team demonstrations should have but one objective, to display to the public the extreme discipline and team-work that is capable given their military's training capability. The pilots who fly these shows are "products" of their country's training program. The air forces of the world sponsor such teams mainly under the guise of recruitment. Consequently, in-country military-team displays help motivate young people into considering a life in the military, perhaps not as a pilot, but as ground crew or technicians. This explains why these shows often begin on the ground with a very sharp display of military discipline and teamwork well before the first aircraft takes off. The fundamental principles that are on display are extreme discipline and teamwork – they follow their leader.

Contrast that thought with the objectives and psychology of a single aerobatic stunt act. These pilots are at the show to provide 'seat-of-the-pants' entertainment. Extremely well accomplished aerobatics pilots, these individuals have learned how to take their skills learned in aerobatic competition to perform an aerobatic display. However, there is often much more associated with this discipline than just aerobatics. Some of these shows incorporate such acts as wing-walkers or extreme low altitude ribbon cutting, to name a few. While these manoeuvres have absolutely nothing to do with the art or aerobatics, they are often incorporated to provide that heart stopping "wow" effect for the spectator – airshows are, after all, a form of 'entertainment'.

There is thus very little connection between competitive aerobatics flown at higher altitudes and judged for accuracy in manoeuvres and those sequences flown in airshows for display purposes. The stunt pilot show is a display of one pilot's flying skills and the ability to accept risk for the thrills and enjoyment of the spectator. Those skills, acquired by experience, are based solely on his ability to fly the aircraft. So how does all this fit psychologically? Most of us have grown up watching airshows and can easily recall wonderful formation display teams and heart-stopping barnstormer acts. Unfortunately, there is a desire as airshow pilots, to *do it all* based on our perception of a perfect display that would incorporate all of the wonderful things that we have seen at shows in our lives.

Sadly, understanding the fundamental unique differences in these disciplines is something that many adult performers have not fully appreciated. The tragic accident of the Italian Air Force's *Frecce Tricolori* in Germany in 1988 was not necessarily the result of an incorrect line-up or any other technicality, but the result of mistaken objectives. The team would have had the desired effect of demonstrating the extreme discipline of formation flight without the need to provide a heart-stopping cross-over of three different elements of the ten-ship formation. That accident clearly stands out as having crossed the line on the fundamental understanding of what the real objectives are for the formation team and what stunt-pilots are paid to do. Heart-stopping "wow" effects should be left to those professionals who have dedicated their life to it and their show's very existence depends on it.

Conversely, the job of the corporate demonstration pilot is NOT to place on display his flying skills or risks that he is willing to accept for the purpose of exciting the potential customer. His sole purpose needs to be the demonstration of the aircraft to potential customers. It is imperative for the demonstration pilot to design the show routine ensuring that no part of the sequence would be seen as a display of pilot skills or a display of aerobatic manoeuvres, but only those manoeuvres that strictly demonstrates aircraft capability.

There are very powerful psychological motivators, probably ingrained from childhood that drives demonstration pilots to include some heart-stopping aerobatics in their demonstration routine. The demonstration pilot should reject all of these notions and should consider the many suggestions from colleagues who would no doubt disagree, calling for an added roll here of perhaps a four-point roll there that would fit into the presentation. The demonstration pilot should diplomatically cast-off all of those suggestions knowing that aerobatics is not the fundamental objective, demonstration of capability is.

The accident of the SU-30MK at Paris Airshow 1996 while completing a half-Cuban eight followed up with multiple 360º rolls while trying to hold a 45º down-line, serves to make the point. The pilot's objective should have been a show demonstrating the product capability to potential customers. There is certainly not a single aviation customer for the Su-30 in the world that doubts the aircraft is capable of a half-Cuban eight and multiple 360º rolls – so why do them at such low heights? In a Reuters report on 13 June 99, the test pilot Viacheslav Averyanov apologised saying he accepted the blame after attempting an ambitious aerial manoeuvre. "Sorry, I did one too many revolutions in a flat corkscrew and I couldn't pull her out. I didn't have the altitude to get the plane out of the manoeuvre," Averyanov was quoted as saying.

However, the real problem was the fundamental psychological selection of that manoeuvre for that show. The pilot attempted to incorporate competitive aerobatics that is best left to a competitive aerobatic aircraft such as the Extra-300 and flown by an aerobatic pilot. The selection of manoeuvres was based on a desire to show that *he* could fly aerobatics precisely and not based on the fundamental objective of demonstrating what the aircraft is capable of doing. Consequently, once again the common thread in these accidents was crossing the line from one discipline to another. The result of a fundamental misunderstanding of what that pilot should have been trying to achieve in the show cannot be violated without consequences.

MANAGEMENT'S ROLE

The subject of demonstration flying, pilot preparation and support must be one for serious consideration by management irrespective of whether management is the Manufacturer, Company, sponsor or military. In the case of the private owner, there is not necessarily management oversight. The selection of demonstration pilots should be done with the utmost care and management should focus on candidates that demonstrate total dedication to demonstration flying, not academic brilliance. Most importantly, there must be a sound link between management and the demonstration pilot.

Management must demand that the profiles and manoeuvres are practiced regularly since a crash could have serious ramifications not only for the product's commercial viability, but also their management careers. Management has a serious responsibility for the safety of the pilot and the aircraft by ensuring that the pilot is given every opportunity for regular, realistic demonstration practice without having to argue or plead for it. Ideally, a number of flying hours, together with the appropriate authority, should always be provided for in any new aircraft contract. In the majority of cases, responsible managers appreciate such requirements and provide their full backing, realising that failure to provide the necessary tangible support could bring safety regulation litigation against the Company.

On many occasions, a particular product demonstration flight may be requested by marketing during a stringent phase of the flight test programme and opportunities for practice may be limited. This is one of the practical problems of demonstrating prototype aircraft to potential customers and is a natural step in any developmental programme, it cannot be avoided.

Management must ensure that the test pilot is allotted training flights to be able to build-up to a satisfactory and safe presentation level. If time is severely restricted for practice, an option remains to utilise a certain percentage of the flight test sortie for such training, provided of course that the flight envelope, test configuration and developmental status permits. When a demonstration is home based, the test facilities can be utilised as an extension of the demonstration allowing visitors to appreciate both the technical capabilities of the aircraft and also the flight test department. Different devices can be used that are not normally carried or used in a public show, jet-assisted takeoff units, arresting systems, ground handling equipment and armament.

There is no doubt that product demonstration flying is a potentially high-risk task that accompanies the test pilot throughout his appointment, unlike other specific high-risk test manoeuvres that form part of the test pilot's remit and only occur during certain phases of a test programme. Not every pilot will have the privilege of flying an aircraft to the limit of its performance in unfamiliar circumstances and under considerable psychological pressure.

TARGET AUDIENCE

Test pilots will invariably be used by the Manufacturer to perform product demonstrations and management's assessment of the added value of that pilot to the company, will be considered in terms of how successful the marketing venture turns out to be. A low-key performance will certainly have the potential customer making direct comparisons with the performance demonstrated by competing companies. The prospective customer, realising the power vested in being the buyer, will not be afraid to ask really embarrassing questions like: "if your aircraft is as good as you say it is, why can't it do the manoeuvres of aircraft X that was displayed at Y". Similarly, an impressive demonstration will go a long way to influencing the prospective customer; the name of the aircraft and the company producing it, will certainly be remembered by the buyer.

Commercial demonstration flying usually has to cater to the widest spectrum of spectator needs, from the professional military Services or prospective civilian customers, to the "man in the street" and will even include a small percentage of perfectionists who wish to see the hallmark of the true professional. In the very competitive aerospace industry, a dull display could jeopardise the potential sale of the aircraft, even worse, an accident may cost the company millions of dollars in export orders.

COMMERCIAL SALES PITCH

The product demonstration sales effort is not only restricted to the actual demonstration flight, there are several other commercial considerations that can be used to 'liven' up the demonstration. Modern society seems to thrive on the 'wow' effect, people are no longer satisfied with the standard routines and displays – spectators seem to be continuously looking for that extra special 'something'.

Aircraft configuration, public address and press briefings, all constitute peripheral contributions that can enhance the saleability and promotion of the aircraft and the display pilot. In wet and moist conditions, vortex of all types are visible, providing the spectators with ideal trajectory displays, when used cleverly, they can increase the aesthetic appeal of the show significantly. High-speed aircraft can also increase the spectacular appeal by utilising what is known as the 'Prandtl-Glauert singularity', the intense and rapid formation of condensation over the expansive corners of the airframe – the predictability of the phenomenon is however not certain.

Using the inherent potential of the aircraft, it is certainly possible to produce very aesthetic appealing features such as using paint schemes or the aircraft's name painted boldly on the aircraft. However, the effect of paint on aircraft weight should be considered and also the possible adverse effects on handling qualities caused by paint creases on airflow disruptions such as the joining of two or more colours in a critical area i.e. wing leading edge that could affect the stalling speed or flying characteristics.

COMMERCIAL DEMONSTRATION FLIGHT GUIDELINES

Deviating from the discourse on airshow type display flying to the more commercially orientated product demonstration flights, it is necessary to realise that this type of demonstration flying is constrained by the same limitations and hazards as display flying at airshows. Commercial demonstration flying, however, has an added liability, that of a potential customer and as such, can be one of the burdens of flight-testing, but can also be one of the most enjoyable forms of display flying.

This of course all depends on the developmental status of the aircraft and its associated systems, and also the relationship between the marketing and flight test departments, which if not properly managed, could even end up as a war of attrition between the two departments. The marketing department, driven by the desire to make the sale, are often focussed only on the 'good' while regarding the 'bad' as something to be fixed downstream, in many cases with the prospective customer's funds. The role of the demonstration pilot, therefore, is not only as the test and demonstration pilot, but also as the diplomat and negotiator at a technical level.

The primary aim of the flight demonstration will obviously be focussed on presenting the aircraft in such a fashion that the prospective buyer will have a strong desire to buy, lease or operate the aircraft. The task of the demonstration pilot will therefore be to inspire in the Buyer's evaluation team, and specifically their evaluation pilot, through calmness and quite confidence, that the objectives of the planned tests will be achieved and that all aspects, good and bad, will be demonstrated.

Basic display patterns and profiles must be planned well ahead and must be practiced regularly, despite the possible objections of the flight test management and engineering teams who invariably cannot afford time losses to the flight test programme. It is necessary to understand that from the buyer's point of view, failure to meet their in-Service dates of the new aircraft could unleash the wrath of the media and taxpayer on the prospective buyer and consequently sour relations between the Manufacturer and the Services.

The optimum format of the sequence desired by the company must be determined, taking cognisance of the prospective customer's envisaged utilisation of the aircraft; what are the specific mission relation elements that can be exhibited in the display to emphasise the selling points of the aircraft? Having studied the display arena, the prevailing regulations, the most probable ambient atmospheric conditions and finally the weather options, the demonstration pilot must agree with management what is potentially available to demonstrate.

An alternate plan or 'flat display' should be agreed upon with management. The decision to revert to the flat display will have clearly defined criteria that *will not be changed* on the day under duress from management or even the prospective customer in a bid to provide a vertical display just to impress the customer. Unfortunately, pride, willingness, egotism and enthusiasm to 'please the customer' are significant features in the make-up of your average demonstration pilot, but unscheduled manoeuvres should not suddenly be introduced by overriding commonsense and wisdom, even though the spirit of adventure and 'joie-de- vivre' is supposedly in the make-up of a test pilot.

J. Coreau (Avions Dassault) recommended the following guidelines for demonstrating high performance aircraft within the restrictions imposed by regulations and the requirement to exhibit in minimum time, the agility and power of the aircraft. "The general rule is to demonstrate how much your aircraft's flight characteristics are better than those of the competitors. For a well-trained pilot, a good knowledge of the aircraft's handling and performance characteristics is essential, knowledge of the 'traps', and then of course practice. Before large public shows, it is essential to practice, practice and in the meantime, practice. In some cases there may be only limited time available to practice since the flight test programme milestones still need to be complied with".

BUYER'S TEAM'S REQUIREMENTS

The scope of the demonstration flight and the emphasis will differ, depending on the evaluator. A prospective private owner or managing director of a charter airline, will be extremely interested in performance aspects such as take-off and landing distance, cruising speed, fuel consumption, payload, cost effectiveness, passenger comfort, vibration levels, acoustic noise, etc. If the pilot is a civilian charter operator, the emphasis may lean more towards mission relation, loading cargo, carriage capability, flotation gear, snow skis, etc.

For the military evaluation however, the emphasis is somewhat different; the military perspective will include the entire spectrum or roles and missions. Since the military field is wide and varied, the test pilot and flight test engineer will not be able to address the entire range of issues and a joint test team will usually be required to assist in conducting the evaluation. The military team will include the entire range of specialists acting as members of a joint test team ranging from a test pilot, flight test engineer, and operational squadron pilot through to the logistics and technical support team members.

The relationship between potential customer and marketing agency can best be summed up by Cdr Luciano Forzani, Italian Air Force: "For the helicopter pilot, there is a quiver, a different vibration identified amongst the others, a light, unusual noise are things valuable to the pilot in the helicopter and are part of the dialogue continuously in progress during the flight between pilot and machine. For these reasons, therefore, a demonstration flight with a helicopter becomes something rather complex also from the psychological point of view, as it should be able to create, between the possible customer and the machine, a feeling of harmony and reciprocal respect which might bring them to a mutual understanding. There is no doubt that the company pilot's role is of paramount importance for the achieve-ment of a successful demonstration".

CUSTOMER PILOT

During product demonstration flights, the customer's evaluation pilots and technicians are usually flown on-board to assess the aircraft's ability to meet the mission requirements, often up to the limit of the aircraft's capabilities. Problems can arise when a mission must be planned to the limits of the aircraft's capabilities and it must be flown by the prospective Buyer's test pilot with the Company's demonstration pilot acting as safety-pilot. The problem centres on the fact that the 'guest pilot' or customer will not have had time to build-up the required experience on type to become thoroughly 'au fait' with the aircraft and the associated systems. This situation is usually catered for to some extent by the formal training of test pilots.

The prospective customer's pilot without formal flight test training could typically be the commercial pilot interested in purchasing the aircraft, the managing director of a company or airline, operational squadron pilot or even the Chief of the Air Staff of a particular air force. In such cases, additional pressure is on the demonstration pilot in that a certain amount of diplomacy may be necessary to make the customer's pilot feel 'at home' and then of course, extra alertness is required to cater for the buyer pilot's lack of experience on type. Nevertheless, it is essential to satisfy the customer's requirements to the best of one's ability and in many cases, within the constraints of the security restrictions that may be in force at the seller's facilities.

It should also be considered that the customer's pilot may tend to deny that any specific flying problems experienced during the evaluation are due to a lack of ability or training. If this is the case, a feeling of hostility towards the aircraft on demonstration could be commercially disastrous for the potential commercial sale. It is thus important for the demonstration pilot to avoid such a situation developing and it is essential to obtain as much information on the buyer's pilot to cater for any shortcomings in experience. A fairly good assessment can be made by knowing the guest pilot's experience in terms of aircraft types flown, total hours flown, training background and operational experience.

For the demonstration pilot, another problem area is the 'hands-on' requirements; when to intervene and take-over from the buyer's pilot; how far to let a situation develop before interfering with the controls for safety of flight reasons. The pedigree of air force and airline pilots is generally known, they all have a good general knowledge of flying and maintain a good standard of flying skills. However, as a demonstration pilot, it is not unusual to come across the entire spectrum of pilot skills, from highly experienced professionals, to newly licensed amateurs or even worse, amateurs that think they are professionals. It is these conditions that require that the demonstration pilot have the necessary skills to assess as quickly as possible what the customer pilot's level of skill is. The skills of the demonstration pilot must include the ability, within limits of course, to remain the true diplomat while engendering and creating a feeling of quite confidence between the buyer's pilot and the aircraft.

TEST PLAN

To successfully plan and conduct the product demonstration flight, it is essential to understand the requirements of the prospective buyer's test team and most importantly, to gain the confidence of the prospective buyer's test team – in itself, a most difficult task. Traditionally, marketing efforts worldwide have tended to focus on the 'brochure' performance and a sales pitch that places the importance of 'making the sale', before the prospective customer's satisfaction. Deficiencies, shortcomings and areas still under development tend to be passed over rather haphazardly with promises to 'fix' any problem areas prior to delivery. What the buyer does not always realise is that some of the problems may be 'fixed', yes, but with the buyer's money while others are managed through procedures due to expense. Prospective buyers are usually very mindful of marketing tactics and the 'avalanche of good news' that marketing loads upon the customer. From a marketing perspective, it makes good sense to include a pilot from an air force or Company that uses the specific aircraft type as a member of the seller's briefing team, just to balance the enthusiasm of the marketing effort.

The specific requirements of the prospective buyer should be compiled into a test plan that is briefed to the buyer and the demonstration must be orientated to cater for the prospective customer. In order to achieve this, it is essential to understand the personality of the test team. Are there any cultural aspects that should be included or avoided? Is the evaluation team civilian or military, engineer, manager or marketer or even a financial director? Language may be a major barrier not only to the negotiating process but also to the in-flight communications. In a single-seat or even a dual seat aircraft, it is not possible to take an interpreter on the flight and the demonstration pilot should possess at least a limited ability to converse with the prospective buyer's evaluator; a real world problem, particularly for safety of flight and the handling of in-flight emergencies. This is particularly relevant when dealing military to military since military test and demonstration pilots are not necessarily required to have a command of the Buyer's language. Within the Aerospace Manufacturing business, however, it is not unusual for the specific Company to hire someone with the required language skills to assist in the negotiating and evaluation phase.

The demonstration pilot will have to develop the test plan and a breakdown of flights to satisfy the requirements of both the flight test crew's focus on performance, handling qualities, systems and then also the mission relation exercises of the specific User Requirements e.g. air combat, ground attack, maritime patrol, ASW, etc. Where possible, the demonstration pilot should include demonstrating any specific emergency manoeuvres that will provide the evaluation pilot with confidence in handling the aircraft. For example, single engine operations, simulated forced landing without power, auto-rotation landings, hydraulic and electrical failures where possible, will add value to the scope of the demonstration.

FLIGHT PROFILES

The flight profile generated will of necessity, cater for the experience and personality of the customer, typically ranging on one hand from a familiarisation flight for the financial director, to a comprehensive preview evaluation for the test pilot; the number of flights will be a function of the customer's stated requirements. In all cases, however, the person to convince is the customer's pilot who will make the formal report to his superiors since he will directly influence the decision makers regarding the potential sale of the aircraft. This is true in theory, there are however, many recorded cases where political decisions were and are the overriding factor in the final selection of an aircraft.

This is even truer today that it was in the past. The political pressure imposed by governments making decisions on economic grounds due to offset sales advantages, are becoming the rule rather than the exception – the added value of an aircraft acquisition considers more than just the military benefits; the economic benefits to that particular country are equally important. Was the decision by Austria to purchase twenty-four Eurofighter a decision based on the offset benefits ahead of the financial and technical and military considerations? Not that Eurofighter is in any way inferior, on the contrary, but the cost benefits to the economies through National and Industrial Participation Packages makes such offers irresistible. The Strategic Defence Package compiled by BAe Systems and SAAB for the South African Air Force's purchase of 24 Hawk and 28 Gripen, saw offset and counter-trade reportedly at up to 200% of the purchase value. Such economic arguments make it difficult for the anti-procurement lobbies in a country to sustain arguments against the purchases.

FLIGHT BRIEFING

Just as for any form of display flying, no demonstration flight can be conducted without a comprehensive briefing. The briefing should be conducted by members of the Company's demonstration team, preferably the demonstration pilot since it will help to establish some form of bonding and confidence building prior to the flight. The briefing will address all the aspects of the flight, technical, limitations, procedural and possible emergencies. Most importantly, the enhancing features as well as the problem areas should be openly discussed; it is pointless to cover-up shortcomings in the aircraft or systems under demonstration, much to the disdain of the marketing department, of course. Sooner or later, the prospective buyer will discover the deficiencies and may then consider it a breach of trust, which can only be repaired with difficulty. Ideally, although not always practical, the flight manuals would have been made available to the prospective buyer's evaluation team to study the aircraft and its associated systems prior to arriving for the evaluation.

DEBRIEFINGS

A comprehensive debriefing must follow the flight and the prospective buyer's team should be provided with a comprehensive set of documentation. The debriefing is obviously an extremely critical part of the demonstration flight and it can often, indirectly, be the 'make-or-break' in making the sale. The rate of information flow during the demonstration flight may saturate the evaluation pilot's ability to absorb, analyse and collate. It is in these high workload situations that the demonstration pilot's explanation of occurrences and his ability to recall the sequence of events, can assist the buyer's evaluation pilot in putting together the pieces of the flight's puzzle. The evaluation pilot must be left with no doubts as to exactly what happened, and any doubts that may have arisen during the flight, must be clarified. It is also the ideal opportunity for the demonstration pilot to place in proper perspective the previously briefed enhancing features and of course the deficiencies and shortcomings that may have been demonstrated during the flight.

It is also the first opportunity the demonstration pilot will have to assess the opinion of the evaluation pilot and his reaction to first contact with the aircraft. It is the responsibility of the demonstration pilot to use logical arguments, criticism and praise where appropriate. Under no circumstances should the demonstration pilot take over the task of marketer by trying to 'baffle' the evaluation team with brochures, predictions and excuses, possibly even losing credibility with the Buyer's evaluation team. Irrespective of the experience of the evaluation pilot or team, never sink to the level of patronising, it could sink the whole potential deal – tell it like it is!

In conclusion then, it is evident that a flight demonstration requires from the pilot some fine flying skills and concentration. With regard to personal qualities, however, these depend on the individual who can hardly simulate them if he does not possess them. Cordiality, cheerfulness, a flowing tongue, inspiration of confidence amongst those he meets and of course, an indisputable professional capacity together with the knowledge of the machine, are the essential qualities required from a demonstration pilot rated at a commercial level.

REPORTING

Management, with marketing hovering in close attendance, will usually require the demonstration pilot to make a report, a verbal and a written presentation, regarding the evaluation team's perceptions of the aircraft. Once again, the demonstration pilot must tell it like it is, being very wary of creating expectations to management and marketing. The enthusiasm of the evaluation pilot or evaluation team must not be incorrectly interpreted as a definite yes; the euphoria of a first flight in a new aircraft could produce body language and verbal comments that reflect the enthusiasm of the individual and not necessarily the Airline's Board of Directors or the specific air force's Chief.

The worst case is of course, the demonstration pilot reporting to management that the sale is as 'good as done', leading to the Managing Director making public and media statements regarding the sale, which in the end does not materialise – embarrassing for all parties involved and which could ultimately lead to the demonstration pilot being relieved of the post. Quiet confidence, conservatively presented, should be the highest form of enthusiasm exhibited by the demonstration pilot until the contract is signed and the first aircraft delivered.

Evaluation teams will, in turn, be required to make a verbal presentation and a written report to their immediate seniors, being either airline management, board of directors or Chief's of Armed Forces. To this end, the demonstration pilot should be of assistance to the evaluation team by providing all the necessary documentation, within realistic security constraints, to compile the report. Formal reports will usually be required to be presented within four weeks of returning from the evaluation and the demonstration pilot can assist the evaluation team in formally answering any particular questions by the evaluation team.

If the demonstration aircraft is fitted with a flight-test instrumentation suite, an added advantage is if the evaluation team are provided with the raw data or better yet, processed results of the demonstration tests conducted during the evaluation. It is sometimes also beneficial to obtain copies of the manufacturer's test results conducted during the development of the aircraft.

CONCLUSION

So, how well does an experimental test pilot fit the role of a commercial sales pilot? Unfortunately, many experimental test pilots do not necessarily make good demonstration pilots because the test pilot invariably knows the aircraft very well, having been with the programme for several years. The test pilot may even have been with the programme from the concept stage and has been through all the prototype and developmental phases and shared with the aircraft so many critical and exciting moments. The behaviour of the aircraft holds very few secrets for the test pilot who has become so accustomed and has learned all the compensation required to fly the aircraft, that the response to address unsatisfactory issues with the necessary emphasis, may be lost.

Since the demonstration pilot knows the aircraft thoroughly, he should be able to answer all the questions and must be able to fly the aircraft well. One potential area of conflict exists in that the demonstration pilot might be reluctant to accept any sort of criticism from the potential customer as he will have long before overcome such observations and adapted out of his prior experience.

The flight demonstration nevertheless requires that the demonstration pilot give full attention not only to the flight display, but also to hosting the evaluation team's requirements. Cordiality, diplomacy, positiveness, inspiring confidence, helpfulness and a demonstrated desire to "walk the extra mile" for the prospective customer, will go a long way to facilitating the commercial sale and are essential traits of the demonstration pilot operating within the commercial environment.

CHAPTER 8
FLYING THE DISPLAY

F-16AM MLU of 312 Squadron Royal Netherlands Air Force getting airborne

“The requirements of flying an aircraft to the limits of its capabilities, combined with perfect positioning are incompatible. If you don’t know to solve the problem, don’t go in for low-level demonstrations”. (John Farley, Harrier test pilot for Hawker Siddeley Aviation - Kingston)

INTRODUCTION

Displaying an aircraft to an enthusiastic spectator group is not only a thrill to the spectators, but also to the pilot. The ‘high’ that a pilot derives from flying a good display is difficult to equate to, or compare with any feelings associated with other human activities and can quite possibly be rated as the next level down from achieving a “kill” in air combat. The challenge to the pilot of managing the aircraft’s energy within a confined volume of airspace while keeping the show centred across from the spectator enclosure, is a feat on its own. Add to that the challenge of close ground proximity and the real threat of catastrophe in the event of ‘getting it wrong’, certainly feeds the feeling of satisfaction of successfully completing the display. It is this adrenalin rush that makes pilots commit to the airshow circuit year after year, the thought of eventually having to retire from the circuit pushed aside for every conceivable excuse; why do you think that the airshow circuit has so many ‘old-timers’?

It is no secret that low-level display flying is a hazardous business – display pilots know this and accept the risks, believing that they possess the personal flying skills and confidence to handle the aircraft safely at such low heights. So why do some elect to make it a profession, others a hobby and others, a passion? Irrespective of the type or category of aircraft, the sense of achievement a pilot experiences on completing a successful display flight puts the pilot on a ‘high’. Meeting the challenge of manoeuvring the aircraft at low-level provides a real sense of achievement and satisfaction. Most aviation enthusiasts will never have the opportunity to know what its like to display at low-level in front of thousands of spectators. So, what is involved in the preparation and flying the display? What are the emotions the display pilot experiences before, during and after the display? Irrespective of the type or category of aircraft, the human response and reaction to the “display box” remains the same.

Spectators being entertained to display flying are totally unaware of the stress loading on a display pilot at an airshow, whether it be a ‘Fly-In’ or an international airshow. Whether watching the massive McDonnell Douglas C-17, which uses size and manoeuvrability to amaze or Denel Aviation’s Rooivalk attack helicopter with its agility to basically perform the equivalent basic manoeuvres of its fixed wing counterparts, the challenges remain essentially the same. Displaying a certified in-Service aircraft is one thing, displaying a prototype however, is another. Watching the English Electric Lightning of which the only flying examples today are located at South Africa’s ‘Thunder City’ with its huge amounts of specific excess power, still makes for a spectacular airshow display.

Flying a prototype aircraft at an airshow is usually a lot more complex than flying a standard fleet aircraft. Aircraft under development are, by their very nature, restricted in terms of flight envelope and the extent of the dynamic manoeuvring at an airshow is restricted by the extent of the cleared envelope. These restrictions can be particularly inhibitive to the pilot and if the aircraft is demonstrated too early in the prototype’s life cycle, could lead to adverse publicity, the likes of which could be difficult to counter. The Eurofighter, the first fourth-generation fighter for the Royal Air Force scheduled to enter operational Service by 2006, is such a case, which ex- BAE Systems Test and Demonstration Pilot, Keith Hartley, had to contend with.

C-17A GLOBEMASTER III: CHARLESTON AFB, USA

In principle, the aerial display of the C-17A Globemaster III is no different than for any other aircraft aerial display. We strive to present to the airshow spectator a safe, exciting and enjoyable presentation while maximizing the impressive capabilities of the USAF’s newest and most capable heavy airlift aircraft. The display profile is therefore designed to emphasise the short-field takeoff and landing capabilities, low altitude manoeuvrability, low-speed handling qualities and the impressive acceleration characteristics of the C-17.

Paramount in any aerial display is safety, the C-17 display is no different. The entire process begins with the selection of the display crewmembers. Each crewmember is a highly experienced and qualified C-17 operator with thousands of hours of C-17 experience and usually with flight and display experience in several different types of aircraft. All Aircraft Commanders are, as a minimum requirement, instructor qualified with most also certified as flight examiners in the C-17. The display crew loadmasters are also qualified to these standards.

Once selected, each pilot must complete an airshow display crew certification process and be certified by the aerial display supervisor at each C-17 operating location (Charleston Air Force Base, South Carolina and McChord Air Force Base, Washington). Once certified, prior to performing a display at an event, the proposed display must be submitted and approved by Headquarters, Air Mobility Command, USAF. Also, by regulation, the entire crew must practice the display profile no earlier than five days prior to the scheduled event.

A practice flight at the airshow site is only required if a previous practice flight, normally at home base, could not be accomplished. Due to arrival schedules and Air Traffic Control limitations, display practices prior to shows are not always possible but are obviously preferred by aircrew to allow for familiarity of airfield layout and display area, known as “the box.” If either practice flight requirement cannot be complied with, the C-17 display is prohibited by regulation. Due to the USAF’s extensive operational commitments, there are several display crews at each base and they are rostered according to their availability. Though all crews are certified to identical standards, the ‘prior to event’ practice requirement ensures that the crew is familiar with each other and the display profile, thereby increasing situational awareness and thus enhancing display safety. The normal crew compliment for the C-17 aerial display is four, two pilots flying (Aircraft Commander and Co-Pilot), one loadmaster and uniquely, one additional ‘Safety Pilot’. The very high cockpit workload requires the addition of a ‘Safety Pilot’ who flies with to enhance flight deck safety, help monitor aircraft systems and performance, but as a “non-flying crewmember”. Simply stated, the provision of a third set of eyes and ears to backup the pilot's flying, is an enhancing feature.

Prior to discussing the display profile, let’s take a look at some of the statistics for the C-17A Globemaster III. The aircraft is 174 feet in length with a wingspan of 169 feet 10 inches. The wings are swept at a 25º angle and have 9-foot winglets at the tips. The wing sweep improves high-speed performance while the winglets reduce the required wingspan, enhancing ground manoeuvring and reducing aerodynamic drag for improved cruise performance. The aircraft is capable of carrying a maximum payload of 170,900 pounds and has a maximum takeoff and landing weight of 585,000 pounds. Four Pratt & Whitney F117-PW-100 engines, each producing 40,440 pounds of thrust power the aircraft. During the aerial displays, the aircraft’s gross weight is reduced to as light as possible by carrying only 30,000 pounds of fuel and no cargo, producing a takeoff gross weight of approximately 306,000 pounds and a thrust-to-weight ratio of approximately 0.53; a thrust-to-weight ratio of many third generation fighters. Keeping the gross weight as low as possible allows the demonstration of an impressive maximum rate of climb after take-off, impressively high acceleration rates, tight turning and amazing short-field take-off and stopping distance demonstrations, all enhancing the quality of the display.

To begin the C-17 display, the aircraft is lined up on the runway and the brakes are held while the engines are spooled-up to maximum takeoff thrust. Auto-throttles are engaged and remain engaged throughout the flight in order to allow the electronic engine controls (EECs) to maintain correct power and airspeed settings without the risk of exceeding the engine’s limitations. Aircraft rotation (V_{rot}) is delayed until V_{rot}+10 knots to enable greater pitch authority and reduce the possibility of striking the tail of the aircraft on lift-off. Even with the delayed rotation, the C-17 is capable of lifting-off in as little as 1,500 to 2,000 feet! The sheer physical size of the C-17 getting airborne in such a short distance makes a spectacular start to the display sequence.

Once airborne, the aircraft is further rotated to maintain minimum climb-out speed (V_{mco}) plus 10 knots. This speed equates to 1.2 stall speed (V_s) allowing a safe stall margin and safe manoeuvring ability at 45º of bank during the climb out. This V_{mco}+10 airspeed also provides a safety margin against possible strong wind conditions or unexpected wind gusts making initial pitch attitudes as high as 30º to 35º possible. The initial climb to 1,500 feet above ground level (AGL) can be accomplished prior to reaching the departure end of a 6,000-foot runway! All these factors serve to provide the spectators with an awesome display of the C-17’s short takeoff, climb and acceleration capabilities.

Throughout the remainder of the display, altitudes are maintained between 500 and 1,500 feet AGL, all turns are demonstrated at a minimum of 45º of bank which combined with the inherent stability of the aircraft and the tight turning radius, the entire profile can be flown within a one-mile radius of the show centre. High-speed passes are accomplished at 300 KIAS, with low speed passes accomplished at approximately 130 KIAS. Demonstrating the short-field landing stopping distance and ground manoeuvrability of the aircraft from the assault landing concludes the C-17 display.

Assault landings are accomplished with full flaps (40º flap extension) and a 5º-approach path. The 'powered lift' configuration of the aircraft places the flaps into the wake of the engines and is critical to the short-field landing capability of the aircraft, providing a form of 'blowing'. This configuration is used for both assault (full flaps) and normal (3/4 flaps) landings. Quite uniquely, the concept of powered lift is utilised in the landing flare. In fact, using 'powered lift', the normal aircraft "flare" is not accomplished. Since pitch attitude controls airspeed and engine thrust controls glide path; the 'landing flare' is rather accomplished through the application of power at 50 feet AGL with the nose pitch remaining constant to main gear touch down.

The accuracy with which the C-17 displays are flown is quite remarkable, considering the huge mass and size of the aircraft, but utilising modern aerodynamics and avionics systems is not the sole domain of the fourth generation fighters. Along with 'powered lift', Heads Up Displays (HUDs) are used at both pilot positions and within the HUD presentation, Flight Path Vectoring (FPV) and Approach Path Indicator (API) symbology are used to control a precise approach path and spot landing point in addition to allowing the pilots to continually monitor and evaluate the assault landing without taking their eyes off flying the aircraft. C-17's now incorporate two Core Integrated Processors (CIPs) to provide, as one of their many functions, highly accurate landing and ground roll calculations which allow the aircrew to accurately adjust the spot landing and stopping point directly in front of the airshow crowd line centre point. Powered lift, a 5º approach path, carbon fibre disc brakes, anti-skid and maximum reverse engine thrust enable, the C-17 to achieve a complete stop in 800 to 1,000 feet landing distance!

Once the aircraft is decelerated through a safe ground speed of 90 to 80 KIAS, the flaps and leading edge slats are retracted, maximum reverse thrust is maintained and the aircraft is immediately transitioned into 'powered backing'. Once backing, ground speed is maintained at 10-12 knots, which is impressive for the spectators and keeps the manoeuvre manageable for the aircrew. The loadmaster is positioned in the troop door at the rear of the aircraft, on the side opposite the crowd, to monitor backing speed and provide direct communications to the pilots as deceleration and stopping points are approached. Approaching the designated stopping point, the loadmaster provides a verbal countdown to the pilot and the aircraft is stopped. The C-17 is then immediately re-transitioned from backing to forward taxi towards airshow centre and the display is concluded.

Although the aerial display of the C-17 is performed at low altitudes, high bank angles, low and high airspeeds, safety remains the highest priority incorporated into the profile. Using the safety pilot, the high automation level of the aircraft (i.e. EECs, HUDs, Multifunction Displays, Fly-By-Wire flight controls and numerous other aircraft systems) and keeping all manoeuvres within a safe and 'normal' operating envelope, all enhance the overall safety level of the flight profile. Low speed manoeuvres are designed to be performed at $1.2V_s$ airspeeds building in a 20% safety margin. Most importantly, all the manoeuvres demonstrated are common manoeuvres every C-17 aircrew member is exposed to, just performed in a rapid sequence with a higher degree of precision and timing.

As with any flight, not just the aerial displays, there is no substitute for the experience, proficiency and professionalism of the aircrew themselves. Even with the high levels of automation currently used by today's modern aircraft, pilots must still resist the temptation to become 'over dependant' on automation and still continue to recognize and use basic piloting skills during critical events in a flight. Built in to all display profiles are 'outs' where pilots have the ability to alter a display profile to avoid placing themselves in a situation, which may be unrecoverable. The C-17 aerial display is no different. Our goal is simple; to provide the safest and most dynamic show possible while displaying the impressive capabilities of the world's finest strategic and tactical heavy airlift aircraft!

Major W. Gregg Holden, USAF and Air Force Reserve pilot had flown the T-37, T-38, AT-38, F-16C/D, C-141B, C-17A and Boeing 737/757/767 types. He served as a Display Pilot on the C-17A and T-37 on which he was also qualified as instructor and Flight Examiner. With over 4,500 flight hours logged, Major Holden a C-17A Instructor Pilot with 317 Airlift Squadron, USAF, Charleston Air Force Base, South Carolina and also a First Officer on Boeing 757/767 with American Airlines, New York, demonstrated the C-17 at several major airshows in the USA.

ENGLISH ELECTRIC LIGHTNING: RAF LEUCHARS

"Lightning Mission One-One, two minutes to overhead" . . . the ground controller's voice crackles in the earphones. We are ten miles from the airfield, cruising at a leisurely five miles per minute, running in for a solo aerobatic display at Leuchars, the No. 1 Fighter Airfield in the U.K. Let's think back to how we came to be here. "How do you feel about doing aerobatics this year?" It usually starts like that, a casual question from the Boss. The immediate reaction is one of pleasure-and then doubt as to whether you can produce the required standard. Still, the pleasure far outweighs the doubt, so you decide that yes, you would like to perform. From that moment on, you're on your own. Where do you start? After some research into the problem, you find there are a lot of things to think about.

The Lightning is a heavy, fast aeroplane weighing about the same as two double-decker buses and can travel at 700 mph at sea-level or 1500 mph when six miles high. Because of its wing planform and its primary role as an interceptor, it cannot fly very slowly; minimum speed when landing is about 200 mph, so it has to be flown relatively fast during our display. The faster we go, the more space we are likely to take up…but we want to keep near to the crowd during the display, so how do we cope with that? Fuel is going to be a problem with a consumption rate of approximately 100 gallons a minute, and so we will need to keep a close eye on it and plan our time accordingly.

When we have sorted out the problems of fuel, speed, etc., we now have to work out a series of manoeuvres that will fit into our area and will keep us as close to our spectators as possible. What sort of manoeuvres can we use? Will they fit together so that the speed at the end of one is right for the next one? We know we cannot afford to wait to get the speed right because every 10 seconds we wait takes us a mile further away from the people watching us. These, and many other problems need to be sorted out, but in the end we have what looks, on paper, to be a workable show.

We must next tell the Squadron Commander what we intend to do, and after suitable suggestions for improvements, we can go off and try it in the air. First we remain above 7,000 feet, but gradually we are allowed to come lower until finally we arrive at our display height of 500 feet above the ground. Practice follows practice, polishing the rough edges until our display is acceptable to the connoisseurs, our fellow pilots.

After months of practising, the moment of truth comes: the Battle of Britain display. We've been as far away as Wales, the north of Scotland, and even inside the Arctic Circle to demonstrate this superb aeroplane, but the major show is always the "Battle of Britain Commemoration" and we will need to put everything we've got into it.

About half an hour before takeoff we walk out to the aircraft. Butterflies in the stomach feeling-as usual! Wonder if it shows? Take a quick glance at the sky to check the amount of cloud and its height, the wind direction and the visibility. Looks OK…we'll try for the full show. Check around the aircraft, climb up the ladder, strap in tightly so we don't bang our head on the canopy when we are inverted. Start the Rolls Royce Avon engines, check all twenty-two warning lights are out, call up Air Traffic Control…"Lightning One-One, Taxi."

We get the clearance and line up on the runway. Open the twin throttles and start the take-off run carefully monitoring engine temperatures and RPM. OK. Push the throttle levers forward through the gate and light the reheats. An extra burst of power surges us forward. In

20 seconds we have reached 170 knots and the aircraft lifts smoothly into the air. By the end of the runway we have 280 knots (about 320 mph) and we pull into a steep turn away from the airfield, heading for our holding point on the coast 20 miles to the northeast. We try a quick roll, then hold the aircraft inverted for a few seconds to check that she's flying OK - all seems to be 'ship-shape', and the time has come to commence our run-in. We cross Dundee, heading out to the west of the airfield, bank left to line up with the runway and head straight in, descending in a shallow dive. We cross the airfield boundary low and fast at 400 knots and 250 feet. The front of the 11 Squadron hangar flashes past and we open up to full dry power, then light the reheats. Twin warning-lights flicker-and then go out-showing us we have two good 'burners'.

Two seconds later we have 450 knots and we pull the aircraft up into a vertical climb, sagging under maximum g. Stop pulling the control column, look sideways to confirm we are vertical, then slam the stick sideways to roll through 180º. Pull on to our back - still with maximum g's. The altimeter shows 6,000 feet, one mile high, it looks OK. Continue to pull and the ground reappears through the top of the canopy. We are lined up with the runway, so keep pulling back. The ground rushes up to meet us. But gradually our dive stops and we are back at 500 feet above the runway. Relax the pull. No time to reflect on the last manoeuvre, we're covering the ground too fast for that!

Start to roll left on our slow roll. Kick top rudder to stop the nose dropping below the horizon, keep rolling and we are inverted, hanging in the ejection seat straps as we push less than weightless to hold level. Continue rolling, the horizon coming back the right way up, feeding in left rudder and ten seconds later the roll is complete and we have travelled over a mile to the other side of the airfield.

We roll quickly on to our left side and light the burners again, snatching into a 6g turn. Turn through 90º then roll the wings level and pull the nose up steeply for a wingover to the right. The nose slides around the horizon, and we crane our head back to look for the airfield. Speed is now relatively low at 250 knots and we dive in a steep turn towards the end of the runway. Check that airspeed is increasing and the crowd is down to the left about a half a mile away. With airspeed 350 knots and increasing, pull-up to the vertical again for a half horizontal eight, roll and pull through. Height is 4,500 feet this time and it looks just right, all the 'energy gate' conditions are met. Back down, the g-force making us weigh about four times as heavy. Closer to the enclosure than the first time, keep the g's on to level out and we are back at 500 feet. The crowd goes by in a blur, the speed slides up to 380 knots, and we thrust the stick to the left and light the burners.

Now we pull the aircraft into a maximum 6g level turn to the left as Guardbridge and the chimneys flash by under the left wing. The g is now beginning to have an effect and I notice we are breathing heavily; I also feel a trickle of sweat inside the 'bone-dome'. At the high adrenaline levels it only takes a few minutes into the show routine before the sweat begins to run. The St Andrews road appears directly underneath, showing us that we are turning as tightly as possible. Keep the g's on with the anti-g suit pressing our legs and stomach to stop the blood draining away from the head - can't relax now, must keep the g going. The runway is coming back into view and we look out of the top of the canopy, it feels odd, but we are flying on our side, so it does make sense. The hangars reappear, then the spectators' enclosure. Keep pulling away from the crowd, then reverse with a 'Derry' turn, rolling underneath as we do so, then pull the aircraft around again toward the runway behind us. Keep it low to demonstrate the aircraft's speed and cattle and trees blur underneath in the peripheral vision as we hold 380 knots, holding the bank on hard or we will fly too wide.

Runway beneath us again, roll off the bank fast and pull 6g as we go into a loop. The burners are probably deafening to the spectators, but in the cockpit, the only noise is our laboured breathing over the intercom as we pant within the oxygen mask. Now as we climb past the vertical and pull on to our back passing a height 4,500 feet, the speed drops off to 250 knots, watch the horizon slide below the nose and keep pulling towards the ground. The aircraft buffets and shakes having reached the lift boundary and the airflow is breaking away from the wings. Our dive looks straight, pointing vertically at the ground just to the right of the spectators as we pull out hard at the bottom, keeping the reheats at maximum.

The crowd area is behind us, so roll hard right and turn over the estuary. Roll level and pull the nose up for a wingover to the left as St Andrews disappears underneath the nose. Roll over left and Tentsmuir Forest appears. Dive down, throttling the engines back to keep our speed down and bank over the runway at 500 feet; the picture looks right and energy is good so roll upside down for an inverted run. Pushing forward on the control column to maintain height above the runway, the thought passes through my mind how odd the runway looks out of the top of the canopy. Approaching the end of the runway, the airspeed is now 370 knots.

Pushing the power up to 100% on both engines as the end of runway disappears, we roll the right way up. Light the reheats and pull into a vertical climb; roll again and the countryside revolves in a blur. Pull on to our back and down again towards the airfield but keeping full power on for the final run but even now, with the routine approaching its end, there is not time to relax. Twenty seconds to go to the end, pushing the aircraft down lower to show off the high-speed capabilities. The marker on the airspeed indicator slides relentlessly upwards…500 to 550 to 600 knots. We are travelling at 700 mph, or 95% of the speed of sound, we could go faster but due to Mach number effects and the possibility of inducing a shockwave, it is not allowed. The whole airfield becomes a blur and we pull up into our finale, the vertical climb. A hard continuous pull up into the vertical, the altimeter shows our height is increasing at a phenomenal rate…10,000, 20,000, 30,000 feet in 40 seconds, and we level out, out of view of the spectators.

Relax at last, but only for a few seconds before we have to commence with the approach and landing. We notice how out of breath we are. Check the fuel, there is just enough left to get us down on the ground, so no problem. Roll over onto our backs and pull through to start a dive back for the airfield, banking lazily into the circuit and lowering the flaps and undercarriage. Over the threshold now and let the aircraft sink gently onto the runway. Streaming the brake parachute at 150 knots, it slows us to a walking pace before turning off the runway and taxiing slowly back to dispersal, drained. We stop the engines, wave to the wife and look forward to a much-needed cigarette. Feels funny though, only six minutes ago we were over Dundee starting our run in, and yet it feels like a lifetime.

ROOIVALK ATTACK HELICOPTER:

FARNBOROUGH

When the decision was made in the early nineties to introduce the Rooivalk onto the world's attack helicopter market, it was immediately apparent that part of the marketing campaign would include participation in international airshows. In the Rooivalk's case, the primary reason in the early nineties was to make a statement that the Rooivalk was the front-runner in the attack helicopter field and should thus be considered as an option by buyers. Achieving this presented a considerable challenge to the Rooivalk programme.

Until then, display flights had been limited to flights with South African Air Force (SAAF) pilots, decision-makers and purse-string-holders from both the SAAF and Government Departments. These flights were intended to persuade the client that money was being well spent and that more would be needed. They were tailored to show technical progress towards achieving operational requirements, and were thus displays of segments of typical operational missions. Relatively mundane when observed from the ground, they were totally unsuited to the demands of the public display at an airshow such as Farnborough.

The public display aspect is specifically emphasised because at commercial airshows such as Farnborough, there are actually two flying activities, the exciting and spectacular public flying displays, and the less exciting yet equally important displays of the operational capabilities of the aircraft to potential clients.

Let there be no misunderstanding, making an impressive statement with a helicopter during an airshow is difficult. Helicopter flying displays can be relatively unimpressive when compared to those of fast jets, falling short in speed, rates, vertical capability and of course noise; something was thus needed to create a 'wow' impression. An assessment of the flying displays of attack helicopters during 1992 showed that it was unlikely that any of the competition would be performing aerobatic manoeuvres in the 1993 season, the year of Rooivalk's planned entry into international airshows. The conclusion was that including aerobatics in the flying display would

Flight Lieutenant Keven Mace RAF served as the display pilot with XI probably be successful in establishing a general opinion that the Rooivalk was indeed a frontrunner in the attack helicopter field.

The agility and maneuverability of the aerobatic Rooivalk attack helicopter was a major feature at Farnborough International in 1994. *(Denel Aviation)*

It is important to note that public opinion of an aircraft is often very important to the eventual outcome of a marketing campaign in a given country. Even though aerobatics will probably never be used operationally by an attack helicopter because of the tactical requirement to fly very low, the very fact that it is capable of performing such manoeuvres, makes it a “good” helicopter in the eyes of many. Therefore, with much persuasion, the Rooivalk management team agreed to the development of a flying display sequence that included aerobatics. So began a programme aimed at having a suitably impressive flying display approved for the Dubai and Langkawi airshows at the end of 1993, followed by the inclusion of additional manoeuvres for Farnborough ‘94.

The process followed in designing the Rooivalk display sequence was to identify manoeuvres that were achievable, visually exciting and relevant to the operational attack helicopter role. This resulted in a ‘typically helicopter’ list which included steep turns, hover turns, vertical climbs, and lateral and rearwards flight. The foregoing is not particularly exciting to the casual observer, but to the helicopter expert, much information may be derived by carefully watching even these dull manoeuvres. For example, the helicopter’s ability to maintain speed during a steep turn gives a fair idea of power available, as does the vertical rate of climb. The rate of turn during hover turns indicates the degree of yaw control available while the steadiness of heading during lateral and rearwards flight, provides some idea of the helicopter’s potential as a weapons delivery platform.

The aircraft roll attitude during sideways flight and the speed achieved, indicates its ability to handle crosswinds on the battlefield (the enemy is not always positioned into wind!) and still launch weapons. Interestingly, roll attitude during sideways flight is an aspect where the ‘old-fashioned’ articulated main rotor has an advantage over the reduced articulation of modern designs. This is because the release of some types of weapons with bank angles in excess of 15º is problematical and modern rotors will produce this magnitude of roll angle at relatively low crosswinds of around 20 knots. However, back to the question of including something different into the Rooivalk airshow repertoire in the form of aerobatics.

Aerobatic manoeuvres available to the helicopter exclude spins and any protracted low-g flight, and thus Rooivalk, with its fully articulated main rotor, was potentially capable of performing the classical aerobatics such as the loop, the roll and combinations thereof. The challenge was to determine the extent to which this potential could be realised. Research provided evidence that helicopters with rotor designs similar to that of Rooivalk had performed loops and rolls, but little could be gleaned relating to more important information such as the mechanical loads experienced by, for example, the main rotor system during such manoeuvres. This was something that had to be determined by analysis, simulation and flight-testing.

A significant amount of engineering data had already been acquired during the development test flying of the prototype Rooivalk, and calculations showed that for typical looping and rolling manoeuvres, the structural loads were acceptable. Less confidence existed with regard to the dynamics of the manoeuvres – would there be sufficient speed at the top of the loop, would there be enough control power to initiate and maintain an adequate roll rate, would there be any unmanageable coupling? The first step in answering these unknowns was to apply simulation techniques, but these were of limited value and only supplied rough answers. Thus, by far the bulk of the development of aerobatics on Rooivalk was done in thetried-and-trusted way of incremental flight-testing. This was the fun part!

Having completed the initial stage of assessment, and mindful of the limited time available before the first airshow in Dubai, a decision was made to first develop a barrel roll and a vertical roll, and, for Farnborough '94, to include a half-roll pull-through and a loop. Development was done using the extensively instrumented first Rooivalk prototype but only after I had undergone a session of aerobatic re-familiarisation in the Company's ACE (All Composite Evaluator) trainer aircraft.

The entry to the barrel roll was planned to be from a speed of 140 knots. This speed proved to be a good first estimate, and the build-up of the barrel roll entailed progressively increasing the pull-up rate, the roll rate and the nose-up attitude while monitoring critical parameters via telemetry. A fact that the astute observer may have noticed during the airshows is that a roll in the Rooivalk is always made to the left. This is because of the main rotor dynamics and is related to the direction of rotation of the rotors. Helicopters with the rotors rotating in a direction opposite to that of Rooivalk, will probably always execute rapid rolling manoeuvres to the right because the loads seen by the main rotor components are significantly less than during rolls to the left. Progress in the development of the barrel roll was quick, and after two flights the point was reached where the pull-up rate, the roll rate, the nose-up attitude and the rate of speed reduction, were considered to be satisfactory.

It was time to take a larger step and commit to continuing the rolling and pitching beyond the vertical, implying that the commitment was also to completing the second half of the barrel roll. The Rooivalk performed flawlessly, apart from an autopilot induced bump as the aircraft passed through the vertical and placed unfair demands on the aircraft gyros, which were never intended to deal with inverted attitudes.

The next step, having gained the confidence that the rotor was capable of flying Rooivalk through the barrel roll at a light mass, was to gradually increase the external stores load so that the final manoeuvre could be flown with a fully representative weapons load – not everyone is impressed by an aircraft flying fantastic aerobatics without the appropriate representivity. The goal was achieved, and the manoeuvre was flown with four Mokopa anti-tank missiles and two V3B air-to-air missiles under each stub wing. From there on confidence was high because all the planned airshows were at sea-level, and all of our testing had been done at the rarefied density altitude of about 8, 000 feet, the result of locating the Rooivalk factory on the South African Highveld! All that remained for the first international airshow was to complete the build-up of a vertical roll manoeuvre and then to string together a suitable airshow sequence.

The Rooivalk performance at the Dubai '93 show created quite a stir, the other international attack helicopters being somewhat upstaged by the Rooivalk's manoeuvres. The element of surprise is indeed very useful! The Dubai '93 sequence was successfully used until Farnborough '94, when it became evident that something more would be required to remain competitive. Thus it was back to the drawing board, and, following a process similar to that described above for the development of the roll, the loop and half-roll-pull-through were added to the Rooivalk's display sequence.

The build-up for the loop was done by starting with inclined manoeuvres, i.e. not through the vertical, and then gradually increasing the verticality of the manoeuvre until a true loop was accomplished. Critical considerations were the normal acceleration during the pull-up into the loop, and the minimum speed at the top of the loop. The final manoeuvre was eventually flown by entering at 145 KIAS from a shallow dive and pulling up at slightly less than 2g. The g was held until a nose-up attitude of about 35º was reached whereafter the pitch rate was then maintained until the aircraft reached the inverted position. The half-roll-pull-through was entered from a 35º nose-high attitude at 70 KIAS, and was initiated by applying full left cyclic control with very little yaw pedal input. On reaching the inverted position, the roll was stopped and a positive aft cyclic input allowed the aircraft to be flown out of the dive comfortably.

Essential certification issues included the authorisation of the flying display and the vetting of the display by the airshow authorities. Although the development Rooivalk helicopters were the property of the South African Air Force, the display Rooivalk was placed on the South African Civil Aviation Authority's (CAA) register while performing at international airshows. This arrangement required the CAA to take responsibility for the safety of the airshow routine, and consequently, Denel Aviation spent much time in providing the necessary documentary proof to the CAA. Although a relatively painful process, it was a very good double-check on Denel's own failure modes and safety analyses and was thus considered to have been an effort well spent.

The final hurdle facing display teams was the approval of the show by the airshow Display Safety Committee, both by vetting the proposed paper profiling of the show sequence, and by closely scrutinising flight rehearsals of the show. Generally, major international shows are well organised and controlled, with ample descriptions of the do's and don'ts of the flying displays. Farnborough is exceptional in this regard and the aircrew briefings during Farnborough '94 are well remembered primarily because of the imposing presence of Roger Beazley. He conducted the briefings accompanied by a formidable 'wooden rod' that was noisily thumped on the floor to signal the start of the briefings and to emphasise important points. Discipline was good, no doubt because most of the aircrew wondered where that rod would end up if they transgressed any of the Safety Committee's safety rules and regulations.

Before finalising the display sequence and beginning rehearsals leading to the approval of the display, part of the display pilot's duties include making acquaintance with those authorities controlling the sequence of appearance of the display aircraft. Ideally, the opening slot is the first choice, but this is usually allocated to an aircraft that is commercially important to the local aerospace industry. Our aim for Rooivalk was to get as high as possible in the appearance order, and more importantly, to negotiate a slot between two modestly performing aircraft. A helicopter display following on from the top-of-the-range super-agile fighter display is guaranteed to look really insipid. Finally, a take-off time is agreed. In our case we planned to take-off at the same time as the aircraft preceding us in the display sequence and to climb into the holding area. This allowed us to store energy in the form of height so that we could perform our aerobatics display without the need to waste valuable display time by having to continuously regain the inevitable (for a helicopter!) height lost during the manoeuvres.

Levels of anxiety increased rapidly for the whole team as the time for first rehearsal approached. Planning for an airshow in a distant foreign country begins at least six months in advance of the show date and anxiety seems to increase exponentially from then on until the first rehearsal is successfully concluded. Logistics arrangements are demanding, not least those necessary to transport the helicopter by transport aircraft to the airshow venue. Planning detail is down to a half-day and the implications of a delay in the arrival of the transport aircraft, or damage to the Rooivalk during loading, unloading and re-assembly, obviously increases the suspense.

Display rehearsals allow the display pilot to marry his well-drilled display with the local show environment. Factors such as the air traffic control procedures, landmarks used to position in the holding area and to plan the run-in, wind and weather patterns, the position of the sun at the planned display time, display line markers, avoidance areas, minimum altitudes, emergency procedures and a host of others, need to be studied and practised in order for the pilot to become comfortably familiar with the environment. Minor adjustments to the original display plan are often needed to suit local conditions. For example, the expected sun position may determine the direction of the initial run-in and the most likely wind direction will affect the sequence of the low speed manoeuvres. The latter point is important when demonstrating the sideways or rearwards flying capability of the helicopter since such displays are best made by flying with the wind to develop the highest possible groundspeed.

First-rehearsals are flown "loosely' with the pilot focussing his attention on orientation with the local environmental factors rather than on flying a tight, 'full-on' sequence. However, even during a loose rehearsal, some things are sacrosanct, and the potential resting-place of Roger's wooden staff was a constant reminder that busting the minimum altitude or the display line would be decidedly uncomfortable. Pleading innocence in the event of a transgression at a major airshow is futile, since suitably placed cameras record any deviation below the minimum height or beyond the display line.

Generally, two or three rehearsals suffice for the display pilot to feel comfortable with arranging a validation flight, which is scrutinised by the Flying Control Committee to the finest detail. The rehearsals include both the good weather and the bad weather sequences. The entire sequence must be flown in strict accordance with the written description submitted to the committee prior to the flight, and also according to the defined airshow procedures. Once the display sequence has been validated, no changes may be made to it without the approval of the committee, and all subsequent flights are monitored for compliance.

International airshows are exciting and participating aircrew are certainly privileged to be there. Farnborough, in particular, has a unique aura, and for many display pilots it is an once-in-a-lifetime opportunity. I savoured it, I loved it, I lived it! – as did the crewman and the ground support team. Rooivalk, designed to operate at 8,000 feet density altitude, revelled faultlessly in the dense Farnborough air and never let us down, performing every day, right on cue.

For all display pilots, the major consideration for each display day is the weather; it is that which sets the tone for the rest of the day. At the breaking dawn, peer into the gloom to assess the cloud and wind; is the cloud base high enough for the full show, or will we need to revert to the bad weather show? Is the wind significant, and if so, is it in the prevailing direction, or will we have to moderate the out-of-wind manoeuvres? In London of course, there is always the additional consideration of the traffic, can't afford to miss Roger's daily briefing, you know!

The first deadline is met, Roger is on form. Weather details are absorbed and reminders are issued as is a subtle 'bollockings' where due. Slot times are confirmed, watches are synchronised and best wishes extended. Check weather and wind again. Meet with ground crew and confirm aircraft status and start time - to break the tension, it helps to re-brief the sequence and all procedures with the crewmember. Under these conditions of expectancy, time seems to drag by so slowly towards start time. Further mental preparation is subsidised by watching the preceding displays that give us time to assess the effect of the wind and how the other display pilots deal with it.

Eventually its time to sign the aircraft's books and walk out, all the while subconsciously checking the weather. The pre-flight inspection is completed with nervous banter between the ground crew. Strap-in, check communications with the crewmember and now the emphasis is on 'focus' – committing the mind to the performance – this is a technique used by all top athletes and show business people – total focus on the job at hand. Pre-start checks completed and call Display Control for start clearance and confirmation of the slot time. The anxiety is high, but start-up is on time – now all we can do is hope the systems fire up correctly. With all systems OK, clearance to taxi to the hold is received from ATC, pre take-off checks are completed and we're cleared for take-off to the holding area.

Final systems serviceability checks, into the hover, engines and systems OK, apply maximum collective pitch and accelerate to a 70 kts climb out to the holding area all the while assessing wind and cloud –critical to the display positioning. Level off at holding altitude and check time and the progress of the preceding display while beginning to position in the hold so that the run-in can start as soon as clearance is received. The final pre-display cockpit checks are completed in time to receive the call: "Rooivalk is cleared to display". We're on!

Running-in at 1,700 feet and judging the wind velocity we start a shallow dive so that the first manoeuvre, a half-roll pull-through, starts just beyond the display centre point; of course remembering to keep slightly on the safe side of Roger's display line. With the speed at 140 kts and the height above 1,500 feet, the minimum for the start of the pull-up, the show centre passes abeam, count to five and start the pull up at 1.8g. Stopping the pitch rate at 35º nose-up, we check wings level and wait for the airspeed to bleed to 70 kts. Applying full left cyclic and a dash of left pedal, we roll left, check wings level at the inverted (or a few degrees off-level as needed to compensate for any cross-wind) and pull the nose through quite aggressively (for a helicopter) until 30º nose-down. Check and hold to allow the airspeed to increase for the loop. We're on the safe side of the display line and then disengage the roll channel of the auto-pilot (the prototype autopilot gave unwanted inputs going over the top of the loop) to try and keep the resulting roll perturbations as small as possible all the while making small adjustments to ensure that the lowest part of the loop will be about 100 metres beyond show centre which will allow the quick-stop, which follows the loop, to be completed opposite show centre.

We're about 100 metres beyond show centre and verify that we have met the 'gate' conditions at 150 kts, 700 ft minimum before commencing the pull up at 1.8g while laying off for wind if required. On approaching the vertical, the focus transitions away from the g-meter and on visually keeping the pitch rate steady. Going over the top, the cyclic pressure is relaxed slightly at about 60 kts before commencing the same pull through technique as for the half-roll pull-through that we developed during the routine development phase. Once again checking and adjusting for the display line, the roll channel of the autopilot is re-engaged and power reduced for a descending, decelerating 'swoop'.

Now the moment of transition from the 'aerobatic' to the 'helicopter' show rules with the remainder of the show aimed at emphasising the agility and performance of this powerful helicopter. The regulation change now allows flight at lower heights and slightly closer to the crowd. At Farnborough, the sight lines from the crowd are such that flying lower than 200 ft is pointless since a large percentage of the spectator enclosures are unsighted below 200 ft agl. A lot of judgement is required for the quickstop; at the point where the loop finished, the speed, altitude and wind on exit all needed to be assessed. Rapid adjustments for power, speed and altitude must be made, all the while remembering Roger's rules. Once the 'gate' conditions exist, the collective is lowered and the nose raised to around 25º - adjust collective as required while monitoring the rotor speed, which could increase too rapidly if mishandled.

Now is the time to 'feel' the airspeed and as it decreases to zero, pull in the power and lower the nose into the hover. Pilot workload is now very high, keeping the aircraft steady we enter a hover turn to face the crowd, fast hover turns at about 50º/s left and right through 360º, stopping as crisply as possible between the two turns. Yaw pedal inputs during these turns are against the stops to start and stop, a lovely buzz from the tail rotor while the front cockpit crewmember enjoys an eye-popping few seconds. We stop the turn remembering the wind and bank to 20º for sideways flight - on a zero-wind day we aim for 45 kts groundspeed. We must get it right as it's not good to have insufficient yaw pedal available and to yaw out with some of the most critical audience in the world monitoring the capabilities of the newest attack helicopter on the market.

We accelerate to the selected airspeed with a steady heading and hold the sideways flight at 200 ft while applying 20º opposite roll angle. At the end of the run we allow the aircraft to stop and to accelerate in the opposite sideways direction maintaining the groundspeed at the appropriate maximum. Subconsciously I continually check the height and display line and apply full power pedal 50 metres from show centre to yaw through 90º and this time, into rearwards flight at 45 kts. Just beyond show centre, a yaw out to the right through 180º and the application of full power allows the helicopter to accelerate along the display line. At 80 kts we pull up for a wingover away from the crowd and manage the turn and descend to approach the crowd head-on at 80 kts in line with show centre at 200 feet.

Now we need to judge the point to start the second quick-stop, this time intended to present the belly of the aircraft to the crowd. Stopping the 'quick-stop' overhead the show centre/display line intersection, maximum power is applied and a vertical climb started while hover-turning with the power pedal through 450º. The climb rate for the helicopter is an impressive 1,500ft/min. Once through the turn, lower the nose and increase speed to 65 kts for a maximum power forward climb in preparation for the last two manoeuvres. There is a short period of a few seconds available to check the systems and reassess the wind effect. Offset 45º from the display line, we start the turn reversal towards the display line and

Trevor Ralston, Denel Aviation (South Africa) joined the SAAF in 1967 and graduated top of an 82-strong group of pilots flying Harvards. Having opted to fly helicopters, then in an exciting growth phase in the SAAF, he qualified top pilot on Alouettes and flew operational tours on Alouettes and Super Frelons. He graduated from the Empire Test Pilots' School; the shields on the McKenna and Westland trophies for 1977 record a South African's name. A rapidly evolving aircraft industry in South Africa saw him conducting the first flights of the Alpha XH-1 prototype, the Oryx medium-lift and the Rooivalk attack helicopters.

passing 800 ft, stop the climb at 1,200 ft and accelerate. We assess the position and start a shallow dive to 140 kts before pulling up at 1.8g when about 400 metres from show centre. Stop the pitch rate at 35º nose-up and wait for 100 kts, applying full left cyclic control and very little yaw pedal while watching the world rotate around us.

Recovering to wings level in a slightly nose down attitude, we check the display line clearance, adjust as required, and pitch to 20º nose-up again while reducing power to some 60% and wait for the speed to reduce to near the hover. Pushing forward on the cyclic to generate a pitch rate of about 20º/second and it is held until reaching almost vertically downwards (in fact only about 75º nose-down), I stop the pitch rate and apply full left cyclic control and a healthy 'bootfull' of left pedal to complete a downwards roll through 180º. The display is over and power is reduced as we start a pull out and decelerating rolling turn away from the crowd towards the landing point. Call display control: “Rooivalk complete”. Land, taxi back and shut down, the total elapsed time for the display, 6 minutes 35 seconds. Funny how signing off the books after the display never seems to be possible with a suitably steady hand. Hope Roger does not call.

EUROFIGHTER TYPHOON: FARNBOROUGH INTERNATIONAL

Creating and flying a good display in a prototype high performance agile fighter requires the same principles as for displaying any other aircraft, except that when flying partly developed prototypes, there are some additional factors to be borne in mind. So, how does the display pilot cope with them?

First consideration, what are the aims of the display? For Typhoon, they are to demonstrate the aircraft’s agility and performance to potential customers and secondly, to show the taxpayers something of where their money is being spent. In addition, these aims must be achieved with minimum impact on the development and test-flying programme. Airshows are usually considered within industry as a major distraction from the real task, even though the commercial and political pressures to be seen performing at airshows by actual and potential customers, are obvious.

Secondly, the pilot must carefully work out what performance and handling limitations he must respect. Unlike an in-Service jet, prototypes are usually only partly developed and are subject to a huge number of intrusive and complex limitations. For example, a squadron Eurofighter pilot should have no angle of attack (AOA) limits to worry about, just move the stick where he likes and the flight control system will control everything for him. But on the first Typhoon prototype display routines, there were approximately four pages of AOA limitations because much of the flight envelope had yet to be tested and cleared. This can have a major impact on the manoeuvres the pilot can fly and how he can fly them.

Eurofighter Typhoon DA1 taking of at Farnborough International 2000. (Eurofighter Typhoon)

Next, work out what characteristics you can best display within the limitations. Eurofighter is designed to be very agile and has the ability to rapidly change the flight vector without losing performance. This means looking for sequences of manoeuvres that change quickly from the horizontal to the vertical, from pitching to rolling or pitching and rolling without needing a pause in between to regain speed and energy. This requires a demanding mix of good handling qualities, usable limitations, and plenty of excess thrust. Finally, the sequence needs to be kept tight and close to the crowd, not only so that the spectator doesn’t have to squint to see the aircraft, but to keep their interest throughout the whole display. This all culminates in a sequence that uses a lot of vertical to show off the raw power of the aircraft and mixes looping and turning manoeuvres with high AOA rolling and barrel rolling to show off the agility and minimise distance and time away from crowd centre.

Flight time for display practice is obviously extremely limited since quite apart from the very high cost of flying prototypes, it is usually very difficult to actually get a prototype in the right configuration for display practice because it is very heavily involved in the flight-test programme. Flight practice is thus limited to a few sorties just before the planned airshow. Instead, the initial practice in which the sequence is designed, practiced, adjusted, tweaked and optimised, is carried out in the simulator. Modern flight simulators are a 'godsend' for the display pilot since nowadays they provide a very accurate simulation of the aircraft's handling and performance, and have good quality visual systems that allow the pilot to work on positioning.

Three-dimensional video tables allow the pilot to then 'watch' the display from a variety of positions, including crowd centre. Even better, it is possible for the pilot to actually work through 'real' emergencies like engine failure at critical times, so confirming the safety elements of the sequence. Simulator time is, in comparison with the real aircraft, very cheap and readily available without which, it would be impossible to create and workup a satisfactory display sequence within the time and commercial restrictions. That's not to say that the sequence that comes out of the simulator work-up is perfect, quite often the first flying practices show up weaknesses in positioning or in how the display looks from the ground that requires changes to the sequence, but these are usually minor and don't require a full re-write.

Digressing for a moment, it is worth remembering that a display sequence is a very personal thing; what suits one pilot, may not feel at all comfortable for another in the same aircraft and conditions. For Typhoon displays, the aim is to have two pilots qualified and worked up for the major shows, which provides backup against possible pilot incapacitation and to satisfy aerospace industry politics which is particularly sensitive in multi-national collaborative programmes. Both pilots fly the same sequence; it stops comparisons between pilots and de-personalises the display so as to focus on the aircraft. The purist will comment that this will require a compromise, thereby degrading the total display, but in practice, such compromises are small and insignificant. But if you have difficulty doing someone else's sequence, don't worry, you should always only fly whatever is comfortable for you.

For pre-display preparation, my personal preference is to take a quiet ten minutes before I go to the aircraft and then walk through the display a number of times, thinking through the day's winds, the cloudbase, where it wasn't quite right yesterday, and so on. I find it clarifies and focuses my mind and helps wipe out the other distractions of the day, like press interviews, sales presentations, VIP visits and so on.

You might now think that the hard work's been done and the fun is about to begin, not so. A squadron pilot can expect his aircraft to start reliably and quickly and if it doesn't, he will have a spare aircraft available, ready to go. Prototypes aren't like that. Typhoon has a networked system of computers comparable to a large office, but worse, it's all packed into a single airframe rather than spread out across several floors and many desks. By the time it gets into Service, the complexity will be invisible to the squadron pilot, but development is all about de-bugging such things, making the computers talk to each other in the right order, and avoiding any use of the CTRL-ALT-DEL functions! So, a prototype can be an awkward, bad-tempered, difficult, nasty-minded dog to get started and fully functioning which means you have to allow a lot of time before display time to make sure the aircraft is ready to go.

To put it in perspective, an early prototype Typhoon would often start-up OK in less than ten minutes, but occasionally, and often enough to stop the pilot thinking it wouldn't, it would take 45 to 60 minutes. In some aircraft, this could then lead to problems with fuel burn since the average fighter sitting at idle on the ground for an hour burns a lot of fuel that could then lead to a serviceable aircraft with insufficient fuel to fly the display. Fortunately, even the early Typhoon prototypes had so much excess thrust that it wasn't worth operating on part fuel loads, so there was always ample fuel, even when first holding for more than an hour.

And there is never a spare aircraft available. Even if another prototype was physically available, it would almost certainly not be in the same configuration, would most probably have different limitations and therefore different performance and thus could not fly the planned and practiced sequence. Besides, the sheer cost and the implications of taking another aircraft from the development programme for the duration of the airshow, would prevent provision of a spare aircraft. This puts a lot of pressure on the pilot and groundcrew – the political fallout of failing to display on time, or at all, is huge, where doing it in a single, fragile and temperamental aircraft is not accepted as a valid excuse for failure.

Ideally, taxy in good time and be at the hold before slot time. Use this time to again focus on the sequence, the wind, the positioning. I often do the pre-take-off checks twice since it's very easy to be distracted in the heat of the moment and to miss something because of the unusual environment and the pressures of the display.

Line up, slam into reheat and brakes off before the wheels slide - the day that the savage takeoff doesn't amaze me, is the day I should quit flying! Don't think consciously about the sequence, you know it well enough for it to flow without conscious thought. Don't think consciously about the handling of the aeroplane, your training and flying instincts do a much better subconscious job, but do pay close attention to all those limitations you've studied so much. This actually gets more important the more you get used to the sequence, you naturally tend to tighten the sequence with practice, which takes you ever closer to those limitations. ALWAYS check your 'gates' and 'keys', the essential speeds and heights you need at, for example, the top of a loop before pulling through. If it ain't right, don't do it!

The joy of Typhoon displaying is the sheer performance; the aircraft has so much thrust that the biggest handling challenge is keeping the speed from running away, irrespective of what manoeuvre you're doing. That, and the turning performance, means the aircraft is always pretty well inside the airfield boundary, so staying close isn't a problem. But, that said, the major workload in the sequence, apart from monitoring difficult limitations, is in maintaining position. The wind still has a major effect on aircraft positioning around crowd centre and must be corrected for in every manoeuvre. For example, here's the breakdown of what actually goes on in just a bit of a sequence, a straight low-speed pass into a level low-speed max rate turn into a loop, all positioned on crowd centre. For this example, assume 20 knots of on-crowd, quarter left-to-right wind.

Low-speed flypast around 110 knots, aim off for drift while extending past the crowd centre to allow for drift in the turn. Low-speed turn, roll into turn, max reheat and amazingly, the aircraft starts to accelerate, even at full aft stick. Ease the turn to extend into wind during first half of turn but watch speed closely since if it gets too high, turn radius will increase too much and you'll bust the line at the end of the turn. After about 150º of turn, go full aft stick while checking positioning abeam crowd centre. Hold full back stick for the third quarter of the turn, then adjust as required to stay inside the line and contain the speed. CHECK SPEED – if you've flown it right, you'll have 180 – 190 knots. Pull through the line at the end of the turn to allow for drift during the pull-up.

The low-speed loop is entered after rolling wings level from the turn and unloading and although not necessary for performance with a thrust-to-weight ratio greater than one, it certainly looks good from crowd centre and makes the loop entry look more spirited. Go full aft stick initially and then ease off slightly while checking the key of a minimum 190 knots at 40º nose-up which is good for a tight loop with ample safety on recovery. As the aircraft reaches the vertical, bank gently into wind to correct for drift in the next half of loop; the crowd won't see it, but it stops you drifting across the line when its too late to do anything about it. At the inverted position, check 'gate' conditions of 3,000 ft agl, less than 250 knots (safety check OK, go full back stick from here and the aircraft will recover to level flight with a thousand feet to spare – I like big margins!). Going through downward vertical, bank into wind again so that the wings level pullout to level ends up with drift correction keeping the aircraft inside the line, easing the pull during the last quarter to return smoothly to base height.

Keith Hartley joined the RAF in 1967 and after training did two tours flying the BAe Lightning. He attended ETPS in 1976 and spent the rest of his flying career in test flying, initially at A&AEE Boscombe Down and then with British Aerospace, testing Buccaneer, Phantom, Jaguar, Hawk, Tornado and Eurofighter Typhoon. He has been an air display pilot for 20 years for the company as well as in private display teams, displaying on Lightning, Buccaneer, Hunter, Gnat, Vampire, Venom, Pilatus PC9 and Tucano. He now lives and works in Australia as an aerospace consultant.

That's it! Know your sequence thoroughly and then let your brain fly it – 'be the aeroplane', just think where you want the aeroplane to be next and let your subconscious fly the aircraft there. Check the gates, be strict and if you get it wrong or think you're going to bust the line, 'knock it off' and re-position.

On landing, don't relax. The adrenalin will be rushing around now, and you'll know if it was a good or bad display and that's when it's very easy to forget something. Take some deep breaths, do the after landing checks, and taxy back slowly. Eventually, when you're back on the chocks and shut down, take time with the groundcrew, they'll soon tell you if you were any good, remembering that they deserve your thanks. It takes several hundred people to get a prototype available, worked-up, and serviceable for a display – you're just the guy that gets the publicity; they're the ones who do the work.

CONCLUSION

From the foregoing eight chapters, it is evident that airshows and display flying remains a highly supported form of entertainment for the general public and aviation enthusiasts worldwide. Airshows and display flying have become big business, although only to a small percentage of the world's population, nevertheless, the requirement to satisfy the ever-increasing demands of the fare paying public has increased the pressure on show organizers and display pilots to produce more exhilarating and entertaining airshows and displays. However, there is conclusive evidence that display flying can be a particularly hazardous activity for the pilot who dose not focus with concentrated determination on the safety regulations and on one's own strict professional creed.

MAN's contribution to airshow accident causal factors is a staggering 78%, resulting from the frailty of the human's ability to estimate closure rates and to exercise good judgement under the duress of operating a highly dynamic air vehicle in close proximity to the ground. Airshow accidents, increasing insurance costs, anti-airshow lobbies and the high costs all round, continue to provide the challenges to the survival of airshows and display flying as an entertainment form. It is not necessary for display pilots to 'reinvent the wheel', display pilots have been flying at airshows and demonstrations for nearly one-hundred years; instead, it is essential for the display pilot to learn from the lessons of the past and not to repeat the accidents of the past. In today's highly professional display flying environment, there is no place for 'amateurs'; in this litigious society, there is even less place for the 'daredevil' who disregards the safety regulations that have been developed over the past years.

The display pilot must understand the physics involved in manoeuvring close to the ground, the aircraft's limitations, the pilot's limitations and the limitations imposed by the environment. The science of choreographing a display sequence, the pitfalls, the traps and good energy is essential to the survival of the display pilot. And if the display flight is for commercial sale purposes, the demonstration pilot must know what the minimum criteria is for making a successful sale.

Having read from some of the world's best display pilots, there are certainly several lessons that can be learned and success criteria passed down to increase the survival index of a display pilot. What is obvious though is that in all cases, the display pilot's first consideration is determining and assessing the theoretical capabilities of the aircraft. The next step is determining a sequence matched to the aircraft's capabilities and the pilot's capabilities within the anticipated environment. The principle of gradual build-up through small progressive steps is a prerequisite for each segment of the display routine using other display pilots to critique the routine for aesthetic appeal and safety of flight.

Legacy accidents have confirmed the requirement for the display pilot to conduct practices at the designated show location to be in tune with its individual peculiarities. Detailed consideration and study of environmental factors altitude, weather, crosswind and show regulations for crowd lines, safety plans and volume restrictions must be completed prior to the flight. Pre flight periods must be free from other hindrances of airshow demands e.g. airshow boss, public relations officer, domestic problems, etc. One need only look at the world's top sportsmen and women and study their pre-match activities – its all based on focus, no distractions by peripheral issues. All sport stars stand to lose for failure, is money, and lots of it!

The display pilot stands to lose a life – it is imperative that the display pilot and show organizers make time available for each airshow performer, free of any other distractions in order to get the mind into display gear.

And then there is the energy management aspects that must be optimised throughout the sequence. Respect for the 'energy gate' is imperative if survival is to be guaranteed – during planning, an exit manoeuvre would have been planned for each part of the routine should the key to energy gate not be available – the gate cannot be forced open, the lock can only be opened by the energy keys of speed, altitude and attitude – it is imperative to understand the impact of the environment and manoeuvres on energy while in-flight continuously checking aircraft performance. Maintaining the show volume is not only essential for the aesthetic appeal of the display but most importantly, for spectator and the general public's safety. Collateral damage at an airshow or during a display flight can have far reaching effects on the survivability of a show and as such constant awareness of sun position, cross wind, display line, airfield parameters must be maintained. And then there is situational awareness, continuously being aware of the main threat, the ground.

Airshows and display flying have conclusively been shown to be relatively safe aviation activities but as in all forms of aviation, there is no perfectly safe form of display flying other than to stop of all forms. The challenge that man has been left with is to overcome the deficiencies in human physiology, the inability to make consistently accurate judgement decisions and to operate within the strict boundaries of physics governing display flying.