Display Flying
and
Low Level Aerobatics

First Edition - August 2013

Derived from various material by

Waypoints Aviation Ltd

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and
Low Level Aerobatics

First Edition – August 2013

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Display Flying and Low Level Aerobatics Articles

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Based on an article by Flight Lieutenant AJR Doyle - Royal Air Force
First published in Air Clues in June 1966.

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Introduction

This publication is intended to be a reference document for pilots completing their Low Level Display Approval (LLDA) training, and is normally provided to pilots attending a display flying ground course. It is not intended as a replacement for the ground course and nor should it be used in that context.

While I have undertaken to compile this manual, I am not an experienced display pilot. Not even a little bit! I was fortunate to be part of some Iroquois displays when I was on squadron in the mid eighties and to receive some basic display training during my RNZAF Instructors' Course but that was a very long time ago and I have done little but admire the skills and professional example of many other inspirational display pilots since, both in New Zealand and overseas.

But as I started thinking I might like to dip my toe into the airshow scene and underwent my first low level display approval training session, I thought a précis of notes supporting the course might be helpful. I also thought back to material I had come across in the past and thought someone should collate it into a form that others could get the benefit of.

So this is all I am attempting to do. The content of the manual is the wisdom of others, not mine. Nothing in this manual is new or original, however its quality has been very significantly improved by the knowledge, experience and considered input of NZ Warbirds Instructors, for which I am very grateful. That said any residual errors, omissions and poorly explained bits are mine alone.

The first section contains a précis of notes taken from the slides used in the NZ Warbirds Assn Low Level Display Approval Ground Course. The second section contains articles written by experienced display pilots. These articles are not new or revolutionary, but I have made very slight amendments to bring them a little into the 21st century. The articles may not be completely relevant to your situation but they appear to have plenty of good advice in them. There are also common themes running through them which I found reinforced the main points. There may well be a pearl of wisdom within them which may save you from the embarrassment of media attention, at the very least, or may even save your life.

Should you or anyone you know wish to offer constructive comment on the content of these notes they would be highly valued. Please contact Mark Woodhouse at waypoints@clear.co.nz.

Should you or anyone you know wish to obtain an electronic copy of these notes, they are freely available from the Waypoints website at http://www.waypoints.co.nz/free-stuff or by contacting Mark Woodhouse at waypoints@clear.co.nz.

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NZ WARBIRDS ASSOCIATION

DISPLAY FLYING GROUND COURSE
for a
LOW LEVEL DISPLAY APPROVAL

INTRODUCTION

Course Aims:

- To give an appreciation of the planning, problems and discipline involved in display flying; and,
- To enable pilots to carry out a safe demonstration of an aircraft at low altitude in front of a crowd.

Requirements for the Issue of a Low Level Display Approval (LLDA)

In order to be issued with a LLDA a pilot must:

- Have appropriate experience;
- Have a bona fide reason to hold the approval:
  - To fly in an airshow display;
  - To participate in an aerobatic competition; and/or,
  - To meet specific display requirements.
- Be a member of NZWA or NZ Aerobatic Club; and,
- Hold an Aerobatic Rating. For LL Aerobatic Display Approvals.

Training Requirements

In order to be issued with a LLDA a pilot must:

- Complete a ground course covering:
  - CAA and regulatory requirements;
  - Energy management;
  - Manoeuvres and limits;
  - Human factors;
  - Display lines and limits;
  - Display design; and,
  - Emergencies.
- Complete a flight course covering:
  - Aircraft handling;
  - Individual manoeuvres;
  - Display sequencing;
  - Display positioning;
  - Escape procedures; and,
  - Incremental height reduction.

Recency Requirements

In order to maintain a LLDA current a pilot must:

- Have completed a NZWA approved display ground course in the last 2 years;
- Demonstrate currency/competency in display flying; and,
- Be recommended to hold a LLDA by NZWA authorised Flight Instructor.

REGULATIONS

CAR Part 1 – Definitions

Aerobatic flight means—

(1) an intentional manoeuvre in which the aircraft is in sustained inverted flight or is rolled from upright to inverted or from inverted to upright position; or

(2) manoeuvres such as rolls, loops, spins, upward vertical flight culminating in a stall turn, hammerhead or whip stall, or a combination of such manoeuvres.

Note: Steeply banked, level, climbing, or descending turns necessary during manoeuvres between aerobatic or flypast displays are not considered aerobatic manoeuvres.

Aviation event means—

An event to be conducted below the minimum safe heights prescribed under Part 91 that is—

(1) an air show or practice for an air show; or

(2) an air race or practice for an air race; or

(3) an aerobatic competition; or

(4) aerobatic training or practice.

CAR Part 61 Subpart L – Aerobatic Flight Rating

61.555 Privileges and limitations

Subject to the privileges and limitations of the pilot licence or certificate held, a current aerobatic flight rating authorises the holder to conduct aerobatic manoeuvres within the following limitations:

(3) at a height less than 1500 feet above the surface while not carrying a passenger when authorised by the holder of an aviation recreation organisation certificate issued in accordance with Part 149, if the certificate authorises the holder to organise aviation events.

CAR Part 91 Subpart H – Special Flight Operations

91.701 Aerobatic flight

(c) A pilot-in-command may operate an aircraft in aerobatic flight below a height of 3000 feet above the surface—

(2) below a height of 1500 feet above the surface if the pilot—

(i) holds an aerobatic rating issued in accordance with Part 61; and

(ii) does not perform aerobatic flight below the height authorised in their aerobatic rating; and

(iii) is participating in an aviation event.

(e) A pilot-in-command may operate an aircraft in aerobatic flight over an area that is within a horizontal distance of 600 metres of spectators at an aviation event if the pilot is participating in that aviation event in accordance with rule 91.703.

91.703 Aviation events

(a) No person shall conduct an aviation event, and no person shall operate an aircraft in an aviation event, unless the organiser of the event is the holder of an aviation event authorisation issued by the Director.

(d) A pilot-in-command of an aircraft participating in an aviation event shall—

(1) for display flights, other than a display of agricultural operations or helicopter operations, operate at a height of at least 100 feet above the surface; and

(2) fly the aircraft aligned with reference to a display line sufficiently distanced from spectators so as not to cause undue risk to persons or property on the surface; and

(3) not carry any passengers; and

(4) not fly over any spectator area; and

(5) not conduct any manoeuvre between the display line and any spectator area; and

(6) with the exception of a helicopter hovering or taxiing, not initiate any manoeuvre in the direction of any spectator area.

(e) Paragraph (a) shall not apply to aviation events at which—

(1) not more than 500 people are in attendance; or

(2) there are no more than three participating aircraft; or

(3) the aircraft are in one formation.

NZWA holds a delegation from the Director to authorise aviation events.

AC 91-1 Aviation Events

Aerobatic Displays

3.4.1 Pilots flying aerobatic manoeuvres at an aviation event require an aerobatic rating issued under Part 61 for aerobatic manoeuvres below a height of 3000 feet (above the surface) and down to a height of 1500 feet (above the surface). They will also need to hold a display approval to a lower minimum height from an approved Part 149 organisation for aerobatic manoeuvres below 1500 feet (above the surface) to participate in an aviation event.

Non - Aerobatic Displays

3.4.4 Pilots performing aircraft handling displays that do not include aerobatic manoeuvres should have completed appropriate ground training in display flying that included instruction on flying display manoeuvres, civil aviation rules relevant to display flying and the human factors aspects of display flying by attendance at an RNZAF or an approved Part 149 organisation display flying course.

3.4.5 Pilots performing aircraft handling displays that do not include aerobatic manoeuvres should have completed appropriate flight training in display manoeuvres and if manoeuvres are to be carried out below 500 feet AGL then a minimum height should be specified by an approved Part 149 organisation authorised person.

3.4.6 Pilots participating in air race or airfield attack display activities should hold an aviation event scenario approval for that particular activity from an approved Part 149 organisation.

Table 3.3 Display Line Distances

Display speed	Flypast	Aerobatics
Low energy*	75 metres	150 metres
100 – 250 KIAS	150 metres	220 metres
Above 250 KIAS	220 metres	220 metres

* Low Energy is defined as having a mass of less than 2300 kgs and a maximum TAS of 100 knots. This category is designed to cover most light aircraft, helicopters and aircraft of a vintage, homebuilt or historic nature while carrying out such activities as “crazy flying”, dropping of articles, and underslung load demonstrations.

Note: 91.703 requires a minimum display height of 100 feet except for helicopter or agricultural operations. Certain displays, such as “crazy clown” flying and other low energy aircraft may be granted an exemption by the Director to operate below 100 feet if the Display Organiser can provide sufficient information to the Director to show that an equivalent level of safety can be achieved and that spectator safety is not compromised.

3.3.7 Display aircraft are not permitted to overfly the spectator enclosure or visitor parking areas, except on ingress and egress from their displays, and then not below a height of 1000 feet.

3.3.10 Any display that commences from the runway should have the departure manoeuvre away from the spectator enclosure.

NZWA Exposition - Procedure 7.4

4.21 When the takeoff runway is closer to the spectator area than the display line to any spectator area, no aerobatic manoeuvre immediately after takeoff should be conducted until the aircraft -

(a) has turned at least 20° towards the display line and away from any spectator area; or

(b) passes the end of the spectator area and then if there are no persons under the flight path.

THE FOUR "M's"

Margins

All activities (not just display flying) must have a safety margin.

The lower the margin, the higher the risk.

Often not an issue of pilot 'skill', but of all the other things that can go wrong.

Manoeuvres

Are they within the capability of:

- The pilot
- The aircraft
- The environment?

Are the manoeuvres inherently safe?

For example - Rolling Lines.

There is a clear point of difference between display and competition aerobatics. Rolling lines for display flying should normally be in an upwards direction except for high performance aircraft.

Minimums

Weather minimums:

- Cloudbase
- Visibility
- Horizon
- Turbulence
- Wind

Altitude minimums:

- Obstacles

Mental (Human Factors)

Is the pilot mentally set for aerobatic flying?

Stress and relaxation?

I'M SAFE

Ego

Performing in front of a crowd

Peer Pressure and 'Display Pressure'

ENERGY MANAGEMENT

Potential vs Kinetic Energy

Energy Sappers (conserving energy)

- High G
- High speed
- Lift Vector control

Low Energy, safer manoeuvres at end?

Looping Diameter - safe to pull through?

Energy checks throughout - "how goes it" - especially before hazardous manoeuvres.

Regaining Energy

MANOEUVRES

Standard Aerobatic Manoeuvres

- Loop
- Aileron roll
- Barrel roll
- Stall turn
- Roll of the top
- Cuban eight and half Cuban
- Slow Roll, Hesitation Rolls
- Linking manoeuvres, (Wing over; Derry turn)

Standard Non-Aerobatic Manoeuvres

- High/Low speed pass
- Canopy up/Belly up pass
- Dirty pass

Linking Manoeuvres

How you get from one manoeuvre to another

Must be set up in terms of energy AND position

No "right" way but there are "wrong" ways

Wingover are often the best:

- They are most flexible in terms of positioning, lookout, energy; but,
- You can't do this for every link!

Guidance – Use 2 wingovers, at about 1/3 and 2/3 through sequence

So what are some other linking manoeuvres?

- Half Cuban
- Reverse Half Cuban
- Stall Turn
- Roll-off-the Top
- Half Roll and Pull Through
- Derry Turn
- Quarter Clover

SEQUENCE PLANNING

Activity
Proximity
Variety
Difficulty(?) – Audience(?)
Non Competition – look skilful to an ice cream licker, but be easy and reliable
Put together a sequence for YOUR aircraft
What manoeuvres are you going to fly?
- Must be 99% guaranteed

What order are you going to do them in?
- Variety (avoid similar manoeuvres back-to-back)
- Energy state (conventionally high e first)

5 minute display = 8 - 10 manoeuvres

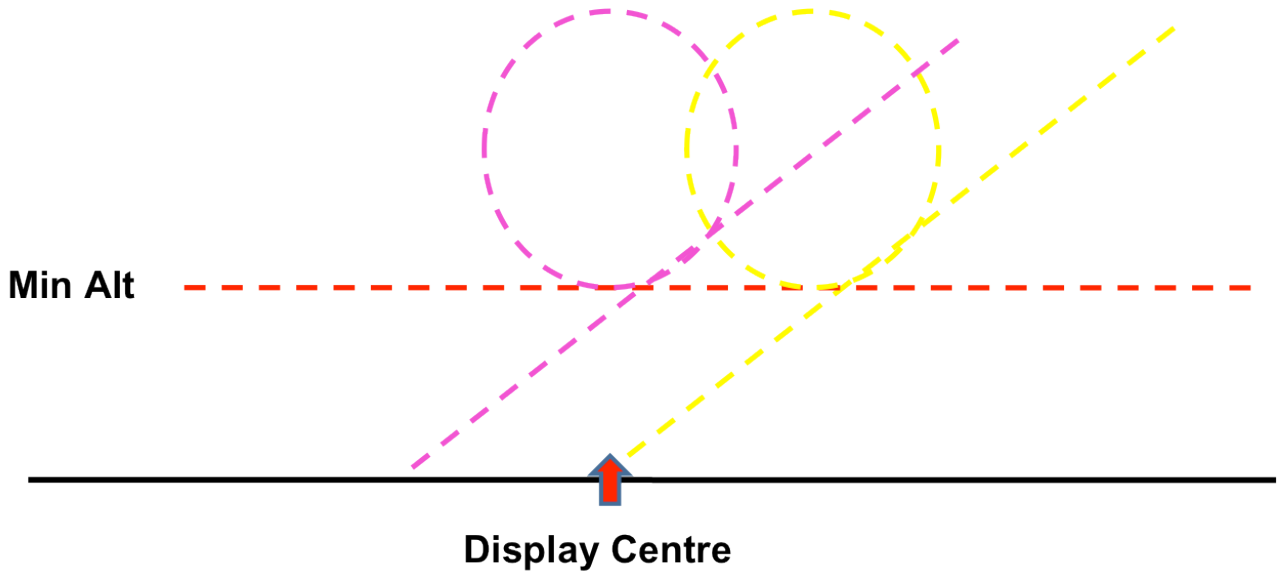
FLOW AND POSITIONING

Manoeuvres

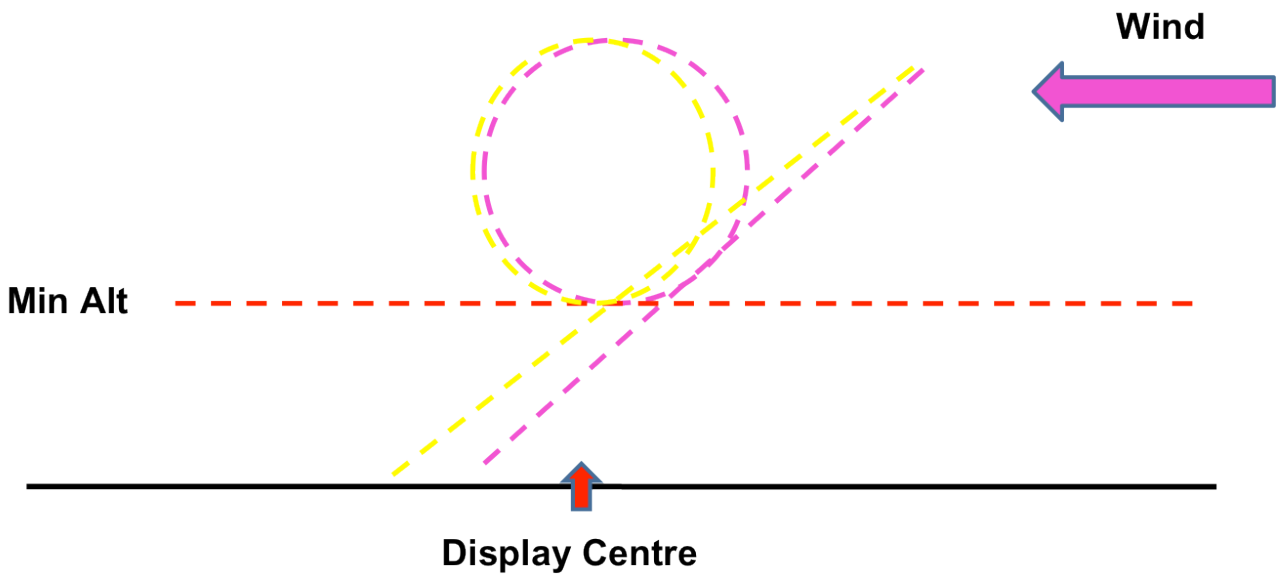
Middle at crowd centre
Symmetry
Flow from one to another – linking /positioning manoeuvres
Entry is important but often stuffed up

Aimpoints

Awareness of display centre



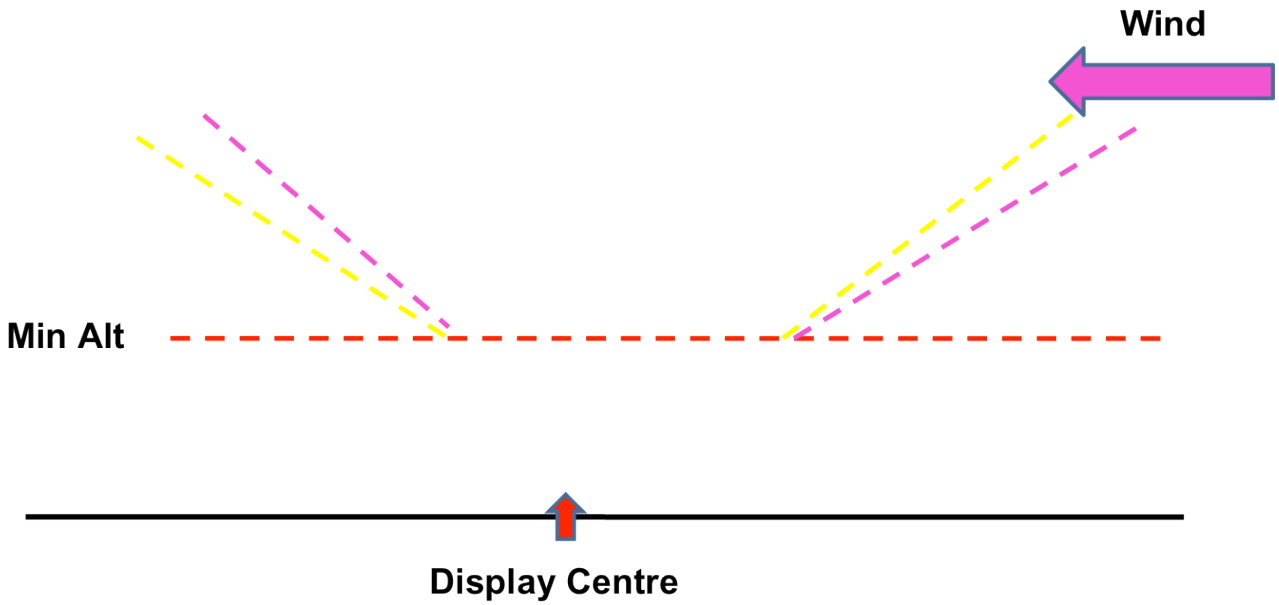
Awareness of wind effect
Steeper dive with tailwind and vice versa



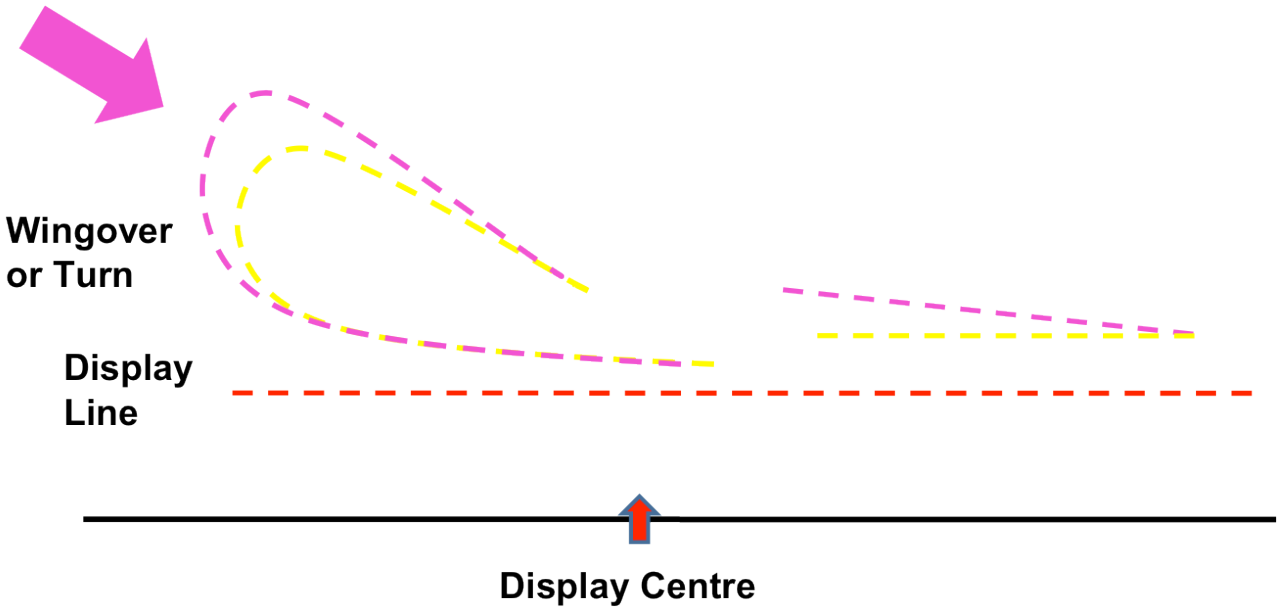
Awareness of display centre/wind effect
Pre tried “speed band” entry speeds, especially minimum entry
Biasing a manoeuvre in strong wind

Allow for Wind Effects

20kts = 1.5 nm in 5min
Downwind vs Upwind wingovers



Tracking for crosswind throughout a manoeuvre



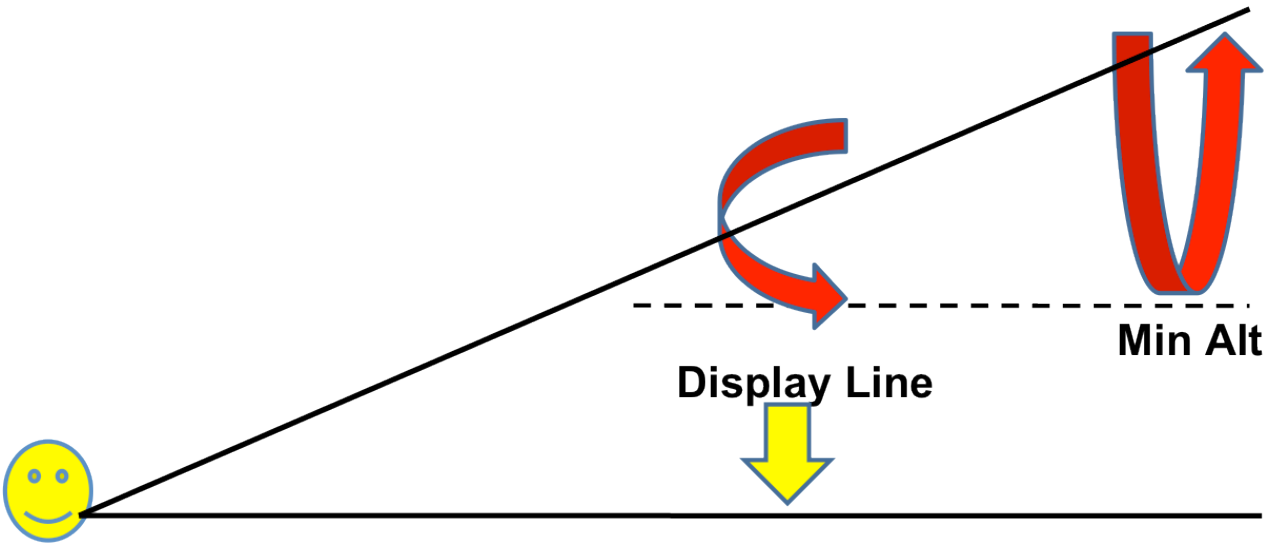
Manoeuvre direction (into or downwind) – to enhance it. Early positioning turn to ensure that the rest of the display works.

- Slow rolls, hesitation rolls etc into wind
- Low passes etc downwind

Make it Easy for Spectators to Watch

Position rolling or flat manoeuvres along display line

Position vertical or high manoeuvres further out from display line



THE WORK UP

Practise each individual manoeuvre until 99%
Work up at altitude
Determine energy states
Ground critique (video)
Don't resist changing it if it is not working – but start the whole work-up process again

THE SHOW

Know the area
Plan for the wind , cloud, crowd front.
Expect and mitigate for the Adrenalin!
Get some quiet time/space before you go
Remember "Mum and the Kids", not "King and Country". Don't push it!
Avoid distractions
It ALWAYS takes longer than you think!
Live to bullshit about it in the Bar.

HAZARDS

Altimeter – QFE
Missed checks – distractions
Cloud /Viz – have a planned low show, or "no show"
Stress on the day
Be an individual thinker not a group thinker
Wake Turbulence

<u>Wake Turbulence</u>

Greatest threat with formations or multi aircraft displays:

- More pronounced in high AOA manoeuvring
- Greater effect with bigger vs smaller aircraft
- Greater danger at low level
- Can cause damage to aircraft

Extract from the inquest into Sir Kenneth Hayr's fatal accident:

> "*... Captain David Miller of the Air Accidents Investigation Branch said a larger Sea Vixen plane banking sharply in front of the Vampire jet during the final display of the day, caused the aircraft to flip over.*
>
> *Video footage of the crash showed how Sir Kenneth had fought without success to bring the plane out of the dive in the five seconds before it hit the ground."*

But also a threat through all phases of flight

EMERGENCIES

Show Stoppage
Airfield Closed
Aircraft control problem
Engine problem

Escape Routes

Always have a way out
Engine failure – must have options
Crowd safety

Dangerous Manoeuvres

Any time you are pulling towards the ground
E.g. Reverse Half Cuban (Pitch up 45 degrees, roll inverted, pull through)
How many ways can this kill you?

The Barrel Roll - probably more airshow accidents from this manoeuvre than anything else
How many ways can it kill you?
What should you look for?

DISPLAY LIMITS

Display Clearances will be issued detailing minimum allowed heights commensurate with their experience and will be reduced incrementally:

- Grade 1. 200 feet passes, 1000 feet aerobatics. This limit encompasses 'intermediate' aerobatic competition and is generally reserved for initial issue.
- Grade 2. 200 feet passes, 800 feet aerobatics. Generally for second issues.
- Grade 3. 100 feet passes, 500 feet aerobatics. This limit encompasses 'advanced' aerobatic competition and is available for subsequent issues.

Restricted issue

100 feet passes, 300 feet aerobatics. This limit is restricted to aerobatic pilots competing in FAI/IAC Unlimited competition events.

Special issue

100 feet passes, 200 feet aerobatics. This limit is restricted to experienced display pilots.

Notes: *1 100 feet is the absolute minimum height permitted by CAA rule part 91.703 (d)*
2 The CFI NZWA may exercise discretion in recognition of previous experience

Aircraft Types

LLDA will be restricted to aircraft types in which the candidate has demonstrated competence. General categories are:

- Group 1 General Aviation (Tiger Moth, Cessna Aerobat etc)
- Group 2 Specialist Aerobatic (Pitts, Giles, Extra etc)
- Group 3 Ex military piston (Yak, Nanchang, Harvard Etc)
- Group 4 Ex Military heavy (>3000kg, P-40, P-51etc)
- Group 5 Ex military Jet.

ADMINISTRATION

Suspension of LLDA

The CFI NZWA or any NZWA Authorised Flight Instructor may suspend a LLDA for:

- Dangerous flying; or,
- A breach of display clearance limits.

A suspended LLDA will only be re-instated after a review of circumstances leading to the suspension by the CFI NZWA.

LLDA Issue Process

- 1 Pilot requests a LLDA
- 2 Supervising instructor makes a recommendation
- 3 NZWA CFI reviews application and issues LLDA
- 4 NZWA CFI issues Logbook sticker and accompanying letter
- 5 it is the LLDA holders responsibility to apply for a renewal
- 6 All approvals will expire on 31 August

Low Level Display Aerobatics

Based on an article by Flight Lieutenant AJR Doyle - Royal Air Force
First published in Air Clues in June 1966.

Introduction

It is not the policy of the Royal Air Force to grant low level display aerobatics the status of a full time occupation. Those who volunteer their services for the 'Silly Season' too often have to rely on their own energy and ingenuity to supply a "do it yourself" course to prepare them for this very specialised form of flying. Air Staff Instructions lay down some basic do's and don'ts for the guidance of authorizing officers, but for the enthusiast facing his or her first season the reference sources for a detailed preparation are few and far between.

This article touches briefly on the many problems that will face a beginner, highlighting the difficulties and supplying some possible solutions, in the hope that it will ease their burden and lead to a higher standard of safety and performance.

Motives

Before embarking on period of low level display aerobatics it is well to take a serious look at your principal motives, for it is this mainspring that will keep you going in the display season when the gilt has begun to wear off the gingerbread. There are a number of possible motives that may lead someone to undertake this activity in the first place, but like many things in life, it tends to look a little different viewed from the inside. Let us examine a few possible motives with a view to seeing whether they will stand up to the wear and tear of reality.

Glamour

Glamour is often a strong motive for getting in on the act in the first place but is apt to wear a bit thin once the real spadework gets under way. No doubt you will have your hand shaken by visiting celebrities and receive thank you letters from grateful organisers, but if it is your dream to be chaired by an adulating crowd then you are in for a nasty let down. Not all of the public are air minded and it is common knowledge among display pilots that one is constantly competing against the attractions of an ice cream cornet!

Add to this that most of your airshows will involve operating from the nearest convenient airfield, and you will begin to realise that the closest you will get to your adoring public is dictated by the positioning of your manoeuvres. There are exceptions to this rule but you will seldom get the opportunity to wine and dine at someone else's expense!

Excitement

A popular misconception is that something that looks thrilling from the outside must feel so inside. If you have anything like a worthwhile routine you will be so busy watching the ASI and the g meter that you won't have time to be anything but hard worked. If you crave excitement go low flying or better still, buy a motorcycle.

Respect of Your Colleagues

Fair enough! But there seem to be few aspects of aviation that stir things up more than low level aerobatics. The possible explanation is that you yourself tend to be more on edge than normal, and you are more readily upset by the little things in life. Whatever the reason, by the time the novelty has worn off, everyone on the airfield is likely to be heartily fed up with the noise you make during practice. Air Traffic moan because you jam up the circuit for five minutes at a time, the CFI becomes paranoiac and is convinced that you are going to kill yourself just to spite him, then he tears his hair out and wonders how the hell he was ever talked into letting you take it on in the first place. And finally, your fellow pilots all secretly believe that they could do better!

If you are married – watch out! That is her future you are balancing on a knife-edge up there, and even if she hates the sight of your ugly mug it is a hard diet to swallow three or four times a week for nearly half a year. Add to this no Saturday shopping and chronic pre-show nerves and you will soon see that this is a motive for giving up the whole idea!

Professional Satisfaction

When your energy flags and things seem to be going against you, this is the one motive that will carry you through when the others have worn thin.

Getting Off On the Right Foot

Having found yourself in the low level aerobatic display business, how do you set about preparing for the displays ahead?

Define the Aim

It sounds corny but it isn't. You must get clear in your own mind just what you are setting out to do. The thing to remember is that commitments have a nasty habit of multiplying with time. If it looks as though you may have to do four shows in the coming summer, prepare for eight and make every effort to be ready early.

This advice is not given tongue-in-cheek, it is in deadly earnest. When the CFI asks if you are ready for an earlier than initially planned start, you will be under real stress to say yes, whether you are or not. So, start practicing early. If you feel that the aerobatics practice and displays might prejudice your main employment or business, or disturb your annual holiday, give up right there and leave the job to someone who is prepared to make the necessary time and energy.

Know your Boss

This doesn't mean that you should start asking your CFI around to dinner, but that you establish exactly to whom you will be responsible as far as display flying is concerned. This will save you the tiresome business of having to liaise with more than one person.

Understand your Boss's Problems

In many cases you will find that your CFI has mixed feelings about authorizing you to undertake low level aerobatic displays. He knows from experience how much work-up is required and how critical the professional execution of a routine is. You, as the performer, have his peace of mind in your hands.

So be as understanding as you can. As soon as your boss realises that your one aim in life is not to rush off and break every rule in the book when his back is turned, the sooner he will trust you. Remember, the regulations have been made for your benefit as well as for the protection of the public.

On the other side of the coin, if something should be suggested which you honestly feel is beyond you - speak your mind. If you say "This is beyond my capability", then no one should press you further.

Setting the Scene

Establish Your Audience

Before you design a routine you must decide just who you are performing for. If you feel that the taxpayer is the one who deserves your attention, then you need something that will make as much noise and look as hair-raising as possible, while at the same time being very safe.

If you are out to please the general public don't waste your energies on academic flying. They would much sooner see you pull up from a hundred feet into a blatantly barrelled climbing roll than a dead level slow roll right down the line.

There is no need to be terribly skilful as the general public can not tell the difference between a stall turn and a wing-over. They will be rapturous over a steep turn in full reheat but put their noses right back into their ice cream as soon as the noise stops, ignoring your immaculate four-point hesitation roll. On the other hand don't expect to command much respect among your fellow aviators. You won't fool them.

'One-off' unrehearsed manoeuvres are also an absolute no-no. The crowd just do not realise that it is difficult and dangerous to attempt to stall-turn in a swept wing heavy aircraft at 3000 feet, so they still think that the steep turn is best. The professionals on the other hand, know that you are not really under control, so you are proving nothing except that this time you were lucky.

And don't imagine that this sort of thing doesn't happen. There was the case of the pilot who tried to open his show with a stall turn in a heavily laden fighter. He had not tried this in practice, and he didn't get another chance as he spun into the car park. Or the pilot who tried a 'one-off' slow speed loop, but the afterburners didn't light. Or what about the classic film of a Javelin slow rolling after takeoff just to show 'em. That certainly made a deep impression.

Perhaps you will decide that the general public are a little too ignorant to provide a reliable yard stick by which to measure your performance. Who else can you turn to? Your crewroom mates? The airfield whizz? Pop the cleaner? The trouble is that each of these people will be looking at your show from a different point of view. One will be comparing it with a show they saw last year in a different type of aircraft and another with what they feels they could do if given the chance. You can not please them all.

I can remember some years ago when the CFS team, after a month of sweat and toil away from the circuit, brought their provisional routine back over the field for the first time. No one wanted unconditional praise, but… there wasn't one manoeuvre that somebody didn't want thrown out as hopeless. One view was that the "Cross" might be worked up to something. In the end there is only one judge who can be relied upon to be consistent, and that is yourself. Since you can hardly watch your own displays, you will have to recruit an assistant, someone who is prepared to watch all of your practices and give uninhibited constructive criticism of what you are achieving.

Building Up a Routine

The single most important factor in deciding what your routine will be is PRESENTATION. However good your aerobatics may be, they will not be much use if the crowd cannot see them. Another important implication of the presentation is the time factor. With high-speed, high-wing-loading aircraft you have got to have a pretty tight routine, or you are only going to get one or two manoeuvres into your six-odd minutes of show time. Rule number one then, is keep it close to the field. Rule number two is, never fly straight and level between manoeuvres. This tip was given to me by a very experiences aerobateur, and it is surprising how much pruning and compressing is required at the beginning of the season to cut out all those little straight bits where you gather an extra knot or two, or make up for a wind effect that you have failed to allow for.

The next stop is to see how much leeway you have got in time and space. What you want are facts not dreams, so be prepared to go to a certain amount of trouble. Take a piece of paper and draw a line on it representing the runway, this will be our reference for the first few weeks of practice. Mark the centre point. Now measure off the runway line, about the centre, the distance your aircraft travels during a slow roll. Since a really slow roll takes about 10 seconds, this distance will be about 1500 yards for 250 knots and 2000 yards for 360 knots. Remember that this is only the bit where you are actually rolling. It does not include the odd second you will need settling down from the previous turn or wing-over.

Now calculate the radius of the best turn that you can make at low level. The formula is:-

$$\text{Radius (in feet)} = \frac{\text{(speed in feet/sec)}}{\text{g (32.2) x load factor (what you see on your g meter)}}$$

All you have to do is smash round a few steep turns at about a thousand feet and note what g you and the aircraft can sustain for a full 360° at various speeds, and substitute these values into the formula. Typical results are:-

250 knots 3 g (Gnat) Radius 1800 feet
I.e., A diameter of about ¾ mile.

360 knots 5 g ½ g (Lightning) Radius 2100 feet
I.e., A diameter of about 1 mile.

It is of interest to note that, although from inside the aircraft you could swear that you were turning tighter at the slower speed, in the Lightning case the radius increases to 3000 feet at 250 kts. It is only in very powerful aircraft of the Lightning class that you can sustain speeds in the turn that put you anywhere near the airframe g limit.

Take this radius and draw two turns at each end of the slow roll line. Make one the absolute minimum for getting back onto the roll heading and the other a full reversed turn, beginning at the end of the slow roll. See fig 1.

Now you have something concrete to work with. If your mount is to be a Strikemaster you will find that you have plenty of room to move about in. If you are flying a heavy, like the Lightning, you will find to your dismay that even the inner (shown dotted) turns, making up the absolute limit pattern, cover an awful lot of the local countryside, let alone the airfield. Wing-overs instead of steep turns help to cut down the diameters, but it is disappointing how little difference it makes in the heavier type of aircraft which lose all their performance once the speed gets near the magic back-side-of-the-drag-curve figure.

Now take a piece of clear acetate sheet, and resisting any temptation to cheat, draw out your proposed sequence of manoeuvres in chinagraph, making all rolls the appropriate length and all turns not less than the minimum radius. This may seem a lot of trouble but it is no good building on dreams, and it is all too easy to draw wingovers like this:-

The result being that you kid yourself that you can get all sorts of combinations of manoeuvres that in reality will not work out!

In very high performance aircraft the sequence almost builds itself as there are only a very limited number of combinations that will fit together without taking you into the next county. As you fit your jigsaw together remember that it is a patent waste of time to come out of a steep turn into a Derry turn right in front of the crowd unless the speed is right as well. The finishing speed of one manoeuvre must be the entry speed of the next.

There are many other secondary factors to bear in mind while constructing a sequence which will make the difference between a good or a bad show. Here are a few of them:-

- The distribution of vertical and horizontal manoeuvres. Obviously it would be unbalanced to have all the rolls first, followed by all the loops. Try also in general to keep high when far away from the crowd and low when near. The acid test being, can a spectator keep you in sight throughout the display without craning his or her neck?

- The distribution of speed can also be important, thus a slow run looks best if preceded by something fast.

- Noise can be used to good advantage to keep the attention of the spectators when you are furthest from them, just as the sudden silence when throttling back from full power can also be an effective attention getter. Since you cannot go changing power up and down ad lib, these effects must be thought about and designed into your sequence from the beginning.

Wind Effect

The effect of wind on a display is more subtle than a cursory examination would suggest. To simplify the problem, divide the wind into two components, one along the display line from left to right, and the other at right angles to it, either on or off crowd. Now let's study the effect of these components on the various types of manoeuvres.

When rolling into wind the distance covered will be shortened, so you will have to start a bit later and roll more slowly than normal. If it is down wind then the effect is reversed and the roll must be started early and hurried slightly. Unfortunately, one aggravates the other, for you finish the into wind roll early, which tends to put your wingover too close to the crowd, you are then faced with a downwind roll which, if anything, you wanted to start further away, not closer. The net result is that your show begins to drift away downwind and you cannot rescue it once it has gone, without an ignominious straight leg while you steam against the current wind in an effort to make up for lost ground.

The wind continues to affect you in the turns and wingovers, and since you spend three times as long in a full turnabout as you do in a slow roll, it is important to compensate. To illustrate this point, Fig 4 shows the effect of a 30 mph wind on a representative steep turn through 360° at 360 kts.

Note the drift is equal to a quarter of the diameter, not the sort of thing that can be ignored.

In all the above cases the technique is the same: ease the back pressure whenever the aircraft is pointing into wind (if you keep the bank on as much as possible the spectators will hardly be aware of what you are doing), and to crank round as hard as possible as you turn downwind. The increase in speed that results from easing the turn downwind can be used to get a temporary increase in turning performance as the wind swings round to your rear. It is good practice to over correct all the time as this puts you in a better position for the next manoeuvre. The easiest wind to deal with is the off crowd wind, as you are playing the turn in the second half when the crowd line is in view. The hardest wind to deal with is the on crowd wind component, as you have your back to your reference during the vital moments and are committed once you get the crowd back in view again. It is in this situation that over allowance pays off.

A word of warning here: IN PRACTICE **NEVER** BE TEMPTED TO USE GROUND REFERENCE POINTS, OTHER THAN THE CROWD FRONT. They will do you no good at all when you arrive in the Erehwon circuit for the first time in your life. You must train yourself to work on a crowd front only.

Cases 4a and 4b also apply to looping manoeuvres with the wind blowing in the same plane as the loop. The effect is more pronounced with the wind behind you as the tendency is to gain ground in a loop anyway. Under these circumstances it is almost impossible to make a round loop and the only way to maintain your positioning is to accept this and pull up really early.

The effect of the on or off crowd wind component on loops done along the crowd line, i.e., at right angles to the loop, needs special consideration as will be seen from the following analysis (see Fig 5).

Imagine that you are about to pull up for a loop with the wind blowing from your right. You lay off 10 degrees to the right to keep on the centre line as you pull up. As soon as you get past the vertical that 10 degrees is pointing in the wrong direction, that is it is increasing the drift effect! By the time you get to the pull-out you will be right over the heads of the crowd. The same applies for a loop or half loop begun off the end of a slow roll, in which the drift has been laid off. The only place that you can change that 10 degrees so that it is still acting in your favour is when you are vertical.

The technique then, for a cross-wind loop is this: Lay off the drift on the run in to keep your aircraft tracking along your display line, then as you approach the vertical, roll quickly through at least twice the number of degrees that you laid off in the pull-up, towards the direction that the wind is coming from. Continue the loop and as you come through the vertical again, roll back to the original angle. This will probably be done instinctively as the crowd line will be in view. The bigger your loop, the more trouble you must take over this correction.

Laid out step by step it sounds a bit complicated but once you have tried it out in practice you will find yourself doing it automatically. The usual fault is to make the corrections too small, with the result that on each manoeuvre the downwind drift accumulates until eventually you have to put in a straight leg to recover. The secret of success is little and often, with a strong bias in favour of overdoing it, for you will never have any difficult in losing a little ground if you do get too far upwind.

Limit Manoeuvres

As your skill increases so you will find that you can fly your aircraft nearer and nearer to its performance limits. Although it's nice to know that you can get round a loop in 300 feet it isn't necessarily advisable to make this the standard for your show. There are a hundred and one little things that can upset the best performance of you or the aircraft, so you need to have something in hand to allow for these. Remember, it is not that these things might happen, they will happen – so be prepared. There is no point in pretending that you can allow for all possibilities. If your aileron jams hard over in a slow roll at 500 feet that is just tough whatsit. On the other hand, there is no future in trailing your coat in the dirt unnecessarily.

I would like to quote the case of the Hunter pilot who put his downwind leg up by 200 feet following an extended inverted break so that he could dead stick if the engine flamed out. The engine did flame out and he did a flame out landing! That is professionalism par excellence.

Left Hand, Right Hand

If you are operating a heavy, high performance type of aircraft you will find that the tight routine necessary to keep you near the airfield makes it surprisingly difficult to change the direction of the show. If you have not had enough practice by the first few shows to cope with both directions at will, your run in direction will need to be fixed with reference to the crowd front. This doesn't always fit in with the plans of the controlling authorities. If this is the case let them know when they write to you for details, and make sure you insist on it. If you are adamant they will play along.

The overall consideration at the beginning of the season is to get something on the boil as soon as possible. Beware of trying to introduce exotic new manoeuvres into your routine too early. It takes quite a time to get your display up to standard without such major distractions.

Something that you may well be able to handle later in the display season, when you are approaching the top of your form, could if attempted too early be just the stumbling block that prevents you ever reaching that form. Be patient and keep within the limits of your current ability.

This gradual build up of form will also show itself in the timing of your sequence. Early in the display season, despite the fact that your calculations show that you should be getting eight manoeuvres into six minutes, your stop watch keeps proving you wrong. Don't despair, by the middle of the season you'll find that you can reel them off, and still have 50 seconds to spare. The opposite happens with the fuel consumption. As you get more used to the aircraft and the sequence, you will fly nearer and nearer to the limits, and this means more power to overcome the drag. With some aircraft fuel and time may be so critical that are not able to accept any change of on-show time once you start engines. If this is the case the display organisers must be left in no doubt as to this requirement.

Bad Weather Show

Despite most displays occurring in summer you will find that there are some days when low cloud prevents you putting in vertical manoeuvres. It is not possible just to miss them out of your routine as the whole thing will then be too short, and in many cases you will not have the right speed and positioning for the next manoeuvre. This means that you must design a completely separate routine for poor weather. The same rules of construction apply and a number of extra items can be introduced to fill the gaps. A run with undercarriage and flap down, a second four or eight-point roll, are popular extras. The nearer you can make it to your full show, the easier it will be to learn, but don't neglect this aspect of preparation as there is every chance that your first show will be in limited weather conditions.

Practice

It must be understood by aspiring low level aerobateurs that it is primarily their own responsibility to ensure that they get enough practice. It is another thing to know what is enough. Although it does depend to some extent on how demanding your routine is, you may as well face the fact that you are unlikely to get enough practice in one season to get your sequence as perfect as you would like. What then can you settle for as being reasonable? The yardstick is your performance.

Before doing a show you must be able to go through your routine every time without making any big mistakes in positioning, entry speeds and heights. By big, I mean enough to make you throw the manoeuvre away, for you must never enter a manoeuvre with the speed too low. Loops and Derry Turns are particularly unforgiving. The ASI must be obeyed absolutely on this score. This is really vital, because when you get out there in front of that crowd it is certain that you'll have a go at it regardless, and this is one of the most common recipes for disaster. You must feel happy with what you are doing and the height at which you are doing it. Don't listen to other people on this subject – ever. Do not hesitate to cut down or simplify your first couple of airshows if you feel that you are a bit short of practice. Pride comes before a fall.

Continuity is as important as the amount of practice. The number of practices may be laid down by your supervising organisation, as the minimum required before an airshow. Remember that this is the minimum and make sure they are spread out over a reasonable period, not all done at the last minute to satisfy the book. Don't be brow-beaten into the deception that the abortive 10 minutes you did last Tuesday constituted a full practice. It is your responsibility to yourself, and to your authorising officer, to make sure that you are properly prepared.

Once you can run through your routine pretty well perfectly under ideal conditions, the time has come to start simulating a display environment. It is very tempting to continue practicing on bright blue days only, up and down your own main runway and feel that you are getting the right sort of preparation. However, is it really good sense to practice under the easiest conditions and then go off to perform under what can be very difficult ones?

Here are many of the distractions that are present at most airshows:-

- Pre-show nerves.
- Navigating at low level, especially if this is not part of your job normally.
- Operating at a strange airfield. Some don't even have a runway, which can be very disturbing if it's the first time you have tried it.
- Non-standard or cluttered R/T. You don't realise how your local Air Traffic Controllers spoil you till they aren't there. Again, some places operate from a mobile tower brought in for the occasion. There are few aids and half the other aircraft seem to be operating on a mixture of hand signals and divine intervention!
- Timing. You have to be pretty important number before they will run their programme to fit your navigation. Generally speaking, if you are two minutes late you will lose two minutes off your time.
- Fuel. What with one thing and another, you will find yourself operating at fuel states that up till now you associated with taxying into dispersal, not setting heading back to base.
- Weather. Some controlling authorities cancel out dead on the limits. Some like to suck it and see. If the clamp coincides with your arrival, it's you that's doing the sucking! Remember that many of the airshows are run on a tight budget, the public pays good money to get there, and it is the airport manager's job to deliver the goods. He may not argue about half a mile and 800 feet, you must.

This list looks formidable, because it is formidable, and it is up to you to make the most of your training periods to acclimatize yourself to these distractions. Overcome your natural inertia and do as many of your practices as possible with one or more of the above limitations built in, e.g., a navigation exercise ending up back at your airfield at an exact time, or a visit to the nearby airfields in your area, again beginning your practice at an exact time.

Weather

As indicated above, there is often difficulty knowing the exact state of the weather until you are actually in it. It is therefore in your own interest to make sure that you get some practice right on the limit in the security of your familiar environment, happy in the knowledge that you can throw it away as soon as you don't like it. Both CFIs and display pilots should resist the temptation to avoid marginal weather on practice days.

Escape Manoeuvres

Remember that in most manoeuvres you are depending on visual references. If you are denied them by unexpected cloud, don't sit there hoping, recover while there is still time. The most sensitive item is the loop. It is all too easy to find yourself suddenly in cloud where you thought there was none. If you are just going over the top and everything is as planned, and you are certain that you will be in the clear again in a few seconds, then it is probably safe to continue, providing you keep the pull going. If you have any doubts at all, do not continue the loop. Ease the pull once you are over the top, roll gently the right way up and find out what the score is, under control.

The crowd will be quite happy if you reappear from an unexpected direction and complete the demonstration. If you cannot get out of the cloud by a reasonable height, thank your stars you didn't carry on with the loop, and go home. The attitude indicator can be a help in this sort of emergency, but beware, even the most sophisticated instruments have a nasty habit of toppling when subjected to continuous high g turns and this is a case of "no gen" being better than "duff gen".

Practise these escape loops until you can roll the right way up more or less by feel. Use the altimeter, ASI and turn needles as your primary instruments for recovery to level flight – they don't topple.

Going into cloud at the top of a wingover can be even worse. Again, the safest system is to practise until you can roll level by feel from any position in the wingover and then recover as for the loop. Do not rely entirely on your altitude indicator; at these heights you cannot afford to be wrong.

Physical Fitness

Once again there are no set formulae, the yardstick is performance. If you can cope with three or four sessions of six minutes each, at a fairly constant 5g, with a sprinkling of -3g, without losing your precision, then you are fit. The test is to be capable of staying at the top of your form while you are in the air. Just remember, it's your neck that you are sticking out and if you are tired you start to make slips, slips that can be fatal. If you are in good physical condition you tire less easily, so don't let fears of ridicule stop you taking exercise if you need it.

Much the same applies to the effect of hangovers. You must know your own limits and stay within them. Some people have a much faster recovery time than others and it's no good kidding yourself that you'll be as right as rain in the morning, if experience shows that you will still be shouting down the porcelain megaphone.

Colds, I have never found much of a limit myself, providing that I could remain at low level, but each pilot must judge for themselves. Do not underestimate the effect that feeling rotten can have on your ability to do the job properly.

Flying Clothing

Comfort is important, but so is strapping in tightly. As these contradict each other to some extent, a compromise must be arrived at. Keeping cool can also be a problem in some aircraft, so bear in mind that things like windscreen demisters are not necessary at low level and they all help to heat up the cockpit. If you do decide to leave off any vital equipment, such as your Mae West, for comfort's sake, just be absolutely sure you know what you are doing. The arguments that persuaded you to leave it off in the first place can sound pretty thin when you are looking down at the water from your parachute.

Do not despise the humble anti-g suit. Its function is to increase your tolerance, not your threshold. I left mine off once for a practice in a Gnat and romped through the first two runs without batting an eyelid. On the third time through, I went out like a light on the recovery from a Derry Turn at 500 feet, and came to in a climb at 2000 feet. That cured me!

The Airshow

An airshow may be counted as a success when you arrive exactly on time, perform your chosen sequence of manoeuvres without error in exactly the right part of the sky, and depart in good order exactly on time. Note that arrival back at base is not included as a necessary ingredient for a good display. If however, you hope to be anything more than a one-day wonder you had better make some arrangements on that score. Although luck, determination, skill, etc, all play their parts, the secret of success is, first and last, detailed preparation. If you fail to fulfil the requirements listed above because of something that you could have anticipated, then it is your fault. Excuses may or may not satisfy the display committee, but they shouldn't satisfy you. The chance to do low level display aerobatics should be a highlight in your flying career, so surely it is worth a little extra effort to ensure that each of the displays you get is as perfect as you can make it. Ask anyone who has done any motor racing or rallying, and they will tell you the same thing. It is the well prepared teams that come out top.

Servicing Away From Your Home Airfield

Since a great number of your displays will be mounted from strange airfields not familiar with your type of aircraft, you may find yourself operating with limited resources. It is too much to expect that you will not meet with unserviceabilities, and a plan should be made well in advance to deal with these. The acid test is, will it affect the show? Do not be distracted with side issues. If you have an alternator failure and it won't stop you performing, then leave it, rather than get involved in repair work that might jeopardise the takeoff time. Whether this line of action might delay the recovery of the aircraft to home base after the show is not your primary concern, so don't give it a thought unit after the show.

If you have spare aircraft as a backup make sure that it is all ready to go when you start up for the show. If it is a tight schedule then get the other pilot to start it up for you. Don't be put off by moans that it is too much trouble. Show an interest in the job in hand and your ground crew will catch your sense of priorities. I have known a ground crew drive 12 hours in a J2, arrive at a strange airfield in the middle of the night, roust the cook out of bed to give them a meal and then change an engine with an engine trolley made out of old packing cases. All that and they never even saw the show! I remember another time when the same team not only kept the display aircraft flying, but made up a jury exhaust stub for the Anson out of an old jam tin so that we could position for the next show.

Fuel

The actual fuel state during the display will be dictated by the distance you have to recover afterwards. The lower the fuel weight the better your aircraft will perform, and it is well worth investigating the possibilities of only partially fuelling when going straight into a show from takeoff. If you run yourself too short you will be distracted by worrying about your safe recovery, on the other hand too much fuel can seriously limit your aircraft's performance. Never start a show at a fuel state that you haven't previously practiced at. I did once and was very unpleasantly surprised at the bottom of the first loop! In a high performance aircraft you will use a lot more fuel on a hot summer afternoon than on a cold spring morning, so be prepared.

Temperatures

When operating heavy aircraft at low speed and high angles of attack you are relying very extensively on thrust to keep you flying. At high temperatures your engine power is reduced and this can cause considerable embarrassment if you go swinging into your routine without allowing for it. Particular care should be taken when displaying at airshows over continental land masses, where the afternoon temperatures can reach figures significantly higher than over islands subject to polar maritime air masses, such as New Zealand

Functional Test

Try to make it a rule never to start a display without first giving your aircraft a quick functional test. The exception will be when you are starting the show from takeoff. Climb to a safe height, say three to four thousand feet, and check the engine acceleration up to full power, and reheat lighting if applicable, pull your maximum permitted g and do a short inverted run.

Getting There

Although most displays have some sort of arrangement for giving you an Air Traffic Controlled approach to the airfield, it is more reliable to get into the habit of making your own way VMC, in contact with the ground. That way you won't be let down suddenly because the system which can be pretty chaotic at some shows, breaks down. Remember that map reading is a skill and as such needs regular practice. If the distance from your operating base is too great to manage the whole trip at low level and the weather prevents you map reading at height, do a instrument procedure let-down at the nearest convenient airfield, with plenty of time in hand, and go VMC contact from there. If the weather is good enough to do a display then it is good enough to map read at low level.

By the time you arrive in the display area you will be thoroughly accustomed to the look of the ground under the current conditions. This is an important point, as it can be dangerously disorientating to pop out of cloud for the first time in ten minutes and find that you are 20 seconds to pull-up with no horizon, poor visibility and an indeterminate cloud base.

Prepare nav charts, marking the time in minutes and seconds at outstanding features to give you an exact on-show time. Choose a convenient holding point a suitable distance along the extended centreline, something nice and easy to see in poor weather, and plan the rest of your trip to this point. On an eight-eighths gin clear day you'll wonder if it was all worth it, but come the day of an unexpected front, or a contrary shift in the wind bringing industrial haze, you may be very grateful for that extra half-hour spent the night before over the dining room table.

Positioning

Having arrived at the right airfield at the right time, you now want to be sure that you present the display to the best possible advantage. It is absolutely amazing how many display pilots, both solo and team leaders, just don't take the trouble to find where the display centre is. They come roaring in and smash up and down the main runway, regardless of the fact that the public are sequestered in a small enclosure right at one end of the field and at a sharp angle to the main runway. If the display organisers do not send you a plan of their airfield with all the relevant details marked on it, ring them up and find out. The AIP charts give a plan of most of the airfields that you are likely to visit, airfield photographs that appear from time to time in aviation magazines and Google Earth are invaluable for giving some idea of what to expect when you arrive at an airfield for the first time. At nearly every show you go to you will find that the crowd is at one end of the runway and at an angle to it, so you can see why it is most important to get some practice using something other than the main runway as a reference.

Wind

Since the wind can have such a vital effect on your positioning, it is most important to have the latest surface wind at the display airfield interpreted into terms of the two components mentioned earlier.

R/T

Air Traffic Control at airshows can be excellent. It can also be appalling and it isn't always readily apparent on receiving advice into which category it falls. The only safe moral is to treat all the information as highly suspicious until proved reliable. Consider making a personal telephone call to the operations officer or their civilian counterpart as near to your takeoff time as possible. Agree on the plan of action, even if it is only confirming the original schedule, and then inform them that if there is any R/T confusion you will stick to this plan. From then on you treat the R/T as though it was confused, and try and confine your communications to brief unequivocal statements of what you are about to do. If something really important comes up they will soon let you know.

This may sound a bit severe, but there is a tendency for both controllers and exhibitors alike to play things off-the-cuff once an airshow has got underway, and one method to avoid ended up in the circuit at the same time as the previous item is to make your own arrival seem as inevitable as possible.

Other Aircraft

However careful the organisers are, there will always be a number of light aircraft swanning about without R/T, either in the show or giving joy rides. They have every right to be there, and in many ways it is probably more their show than yours. However, it is obvious that some of these pilots do not fully appreciate the implications of tons of "screaming aluminium" doing better than 300 kts at deck level, and their cloth taxis are inclined to swim into your field of vision at the most awkward moments.

The only provision you can make is to speak to the organisers beforehand and impress on them that, if they do not clear the circuit COMPLETELY from one minute before your display time to one minute after, they can look forward to a really nasty scrunch to enliven their afternoon. Sound as though you mean it, as indeed you should, and hope that they will do the rest.

Conclusion

All that has gone before may seem a bit of a mouthful, but most of it is commonsense. I have tried to cover as many points as possible in the hope of being some help to those preparing for a season's solo aerobatics for the first time. There is still a rather silly tradition that in some way it is not quite "on" to discuss things like aerobatics seriously, that in some mysterious way one either "has it" or hasn't, like the gentlemen amateurs of bygone days. I am sure that no one really gives credit to this point of view, but it can lead the inexperienced to be more reluctant than they ought to ask questions of those who have had a chance to learn some of the lessons the hard way.

Solo aerobatics are not everyone's cup of tea. If you find that you really are not suited, swallow your pride and quit before it swallows you. If on the other hand, you make a success of it, just remember before you become too enamoured of your own image, that the Royal Air Force doesn't dish out all that extra cash for your personal aggrandisement. You are their representative, and the general public will, to some extent, judge us all on your performance. We would like them to think that we are responsible professional pilots, not a bunch of delinquent whiz kids, so act accordingly.

Finally then, do not be satisfied with less than your best. Do not be too quick to blindly take other people's advice, but never scorn to learn from their experience. Determine to be your own severest critic, then, when you put your trust in your own judgment, it will be well placed. Happy flying!

Take care up there.

Low Level Aerobatics

Based on Training Notes from the RNZAF

Aim

To understand and learn the basic considerations of performing a low level aerobatic display safely.

Introduction

Low level display aerobatics provide the culmination in a pilot's professional development of aerobatic skill, in that they display their ability to all who care to watch. It is an enjoyable, thrilling, and self-satisfying experience which requires much co-ordination, planning and physical effort on the part of the pilot. In addition, it is often performed before a critical and professional audience.

As with all forms of flying, there are certain basic rules which apply most stringently. Whereas errors of judgment or skill in most other types of flying do not necessarily impose any associated hazards, a departure from safety parameters or rehearsed manoeuvres in a low level aerobatic display could well have disastrous consequences. This does not imply that the ability to learn a low level aerobatic sequence and execute it with complete safety, is outside the scope of any trained, dedicated and disciplined pilot of average ability.

The main considerations which will be discussed, apply in general to all aircraft approved for aerobatics, but obviously, safety parameters applicable to different types will vary greatly. The particular parameters quoted in this paper apply to the CT4 A/B Airtrainer and the Strikemaster.

Main Considerations

General Ability

Any pilot, capable of performing the basic aerobatics to a reasonable standard, can be taught to safely perform a low level aerobatic display. There are no special skills or aptitude required, other than a desire to become proficient.

Environment

Initially, the new environment of being close to the ground, and conscious of its proximity when rolling, or being inverted, or pulling through from very low altitudes, tends to be a distraction. However, as with any other phase of flying, the new environment is quickly accepted, and the very real advantage of using the ground as another dimension, assists greatly in achieving desired altitudes, and hence accuracy, during all low level manoeuvres. As an example, it is relatively simple achievement to execute a slow roll within fifty (50) feet of the desired datum at low level, yet often well nigh impossible of the average pilot at normal height.

Parameters

The strict adherence to certain parameters removes all elements of chance and risk from a low level display. The use of these parameters, based on the altimeter and/or air speed indicator, does not preclude the wide use of visual estimation, but simply confirms it. These basic parameters will be discussed in detail.

Minimum Height

The minimum height is dictated by safety requirements in the limit of authorisation and must never be purposely violated. Unless specifically authorised, and this would be a rare occurrence, the minimum height for aerobatic displays in the RNZAF is 500 feet agl, although individual fly pasts may be authorized down to 100 feet agl. Occasions will arise, where through mismanagement, part of this buffer zone will unintentionally be used. It is therefore most necessary to ensure as far as possible that the total 500 feet is always available. The minimum height line is in fact used as a specific accuracy datum, i.e. both the altimeter reading and visual estimation, in all level manoeuvres, including slow and hesitation rolls, inverted run, steep and Derry turns.

Airspeed/Height

Because different types of vertical manoeuvres are performed at varying 'G' levels, and generally not at the aircraft's maximum performance, it is usual to adopt two airspeed/height datums from which a pull-through can be safely accomplished without penetrating the buffer zone. These two combinations should always cover the speed range used in all looping manoeuvres. Where the entry airspeed/height datum is not met the manoeuvre should not be completed – a break off should be effected.

Break Off Altitudes (BOA)

Individual vertical manoeuvres other than those in the looping plane, require a specific break off altitude. For example, spins, tail slides, and vertical downward rolls have individual check heights, and these are usually expressed only as a height datum without specific emphasis on airspeed.

The specific parameters used in the Strikemaster are premised on a 4g pull up. The following may be used as a guide:

- Looping manoeuvres from which a safe pull through can be executed (below 1800 lbs fuel load):
  - 2500 feet agl/150 KIAS
  - 3000 feet agl/150 to 200 KIAS ± 10 KIAS = ± 200 feet
- Spin. BOA 3000 feet agl.
- Vertical Dive. Establish vertical to commence pull out 3000 feet agl.
- Tailslide. Attain 3000 feet agl or break off.

The specific parameters used in the CT4 A/B Airtrainer are also premised on a 4g pull up. The following may be used as a guide:

- Looping manoeuvres from which a safe pull through can be executed:
  - 1200 feet agl/85 KIAS ± 10 KIAS = ± 100 feet
- Vertical (e.g.: Avalanche). Pull up not below 1500 feet agl. BOA 3000 feet agl.
- Vertical Dive. Establish vertical to commence pull out 1200 feet agl.
- Tailslide. Add 200 feet to parameters.

The above parameters are to be used as absolute minima. They may, and usually are, increased slightly until a professional standard is achieved. Unusually high ambient temperatures should also be taken into consideration, as also the knowledge that if ever any doubt exists, maximum performance can only be achieved at full power on the buffet. For the Strikemaster looping parameters are based on 85% RPM. Further, North West condition at Wigram dictate a conservative approach – add 200 feet to your planned heights.

Sequence Development

Before attempting to put together a sequence, initial experience should be gained by practicing slow rolls, pull-throughs, loops, and inverted runs at gradually reducing heights until confidence has been gained. The practice, and modification, of any potential sequence should always be carried out at normal safety height. When the sequence has been reasonably finalised, future practice should be conducted at gradually reducing datum heights. As a guide, bring it down in 1000 feet increments to 2000 feet, then in 500 feet increments to the ultimate 500 feet agl level.

The construction and development of a sequence should include the following points:

- The location, geometry of the site, field of view of the spectators, and ground hazards.
- The type of audience (this determines the theme of the display).
- The time allowed/required. Ideally a solo display should not occupy more than eight minutes. This length will retail a high interest factor yet allow sufficient time to create a well balanced display.
- Balance. Usually a high segment is used as an introduction, followed by a slow speed segment, then the use of one or more low 'G' manoeuvres to allow acceleration back to normal manoeuvring speed. (In the case of the CT4 A/B Airtrainer delete the words usually and acceleration!).

Positioning

As mentioned previously, a thorough area survey (both from the ground and the air) should be carried out to determine the available field of view, ground hazards and any other particular obstructions which may influence the direction in which some particular manoeuvre should be carried out. The 'crowd line' (front line of spectators) is then used as a datum line for the display. The aircraft should ideally always be presented at an elevation angle of 45º to the audience. Obviously this is not possible in looping manoeuvres and a compromise must be reached to keep the aircraft at the correct distance from the viewers. It is usual to employ ground features to create two parallel lines to the crowd line, one at 500 feet from the crowd line for level manoeuvres and the other at about 1000 feet from the crowd line for looping manoeuvres.

Positioning for other vertical manoeuvres is either done by timing or using a specific pull-up point, for a specific manoeuvre, but is of necessity further displaced from the crowd line.

One of the more difficult but important aspects of a display is the development of anticipation and co-ordination required to position the aircraft at the right spot and the correct speed with a minimum of wasted seconds for each individual manoeuvre. However, the 'ends' must be sufficiently varied to maintain interest. Some individual manoeuvres can be used which lead-in directly to another individual manoeuvre (e.g.: a loop or Cuban eight into a steep turn; a slow roll into a loop etc); but wing-overs stall turns, or pull-throughs (after an appropriate amount of pull-ups) should be varied at the 'ends' to create balance.

Wind

Another important aspect of positioning is allowance for wind effect. Strong winds from any direction impose an added difficulty but the worst case and the only one considered here is when the drift is directly towards the crowd. In this case, apart from getting actual experience under such condition, a useful hint is that in looping manoeuvres (where the main difficulty arises), a few degrees of wing drop into wind will assist without destroying the look of the manoeuvre. (In the case of the Airtrainer the radius of loop is such that wings level should be maintained through the loop with positioning being corrected through the connecting wing overs).

It must be remembered however, that further application of the same aileron is required when passing through 'over the top' to keep the slight turn into wind maintained. In addition, the 'ends' should, under these conditions, be made into wind.

Practice

Practice for low level display should follow a regular pattern irrespective of the stage of development attained. The following procedures should always apply:

- Set the altimeter to zero feet on the ground. Make appropriate altimeter subscale adjustments in the air for any subsequent barometric changes.
- Carry out a thorough inverted flight check at a safe altitude. The check should include a check of inverted handling, engine handling, a FOD check and a check of the inverted flight attitude.
- Practice within forced landing range of a suitable airfield or suitable FLWOP field if at all possible.
- Work up (or rather down) gradually. Never bore straight into the sequence at minimum height, even though a high standard may have already been achieved.
- In the early stages, develop the sequence without reference to ground points.
- When ALL of the sequence can be flown safely at the lowest authorized height, introduce a 'crowd line' and concentrate on positioning.
- When the sequence has reached a professional standard, then, and not before, introduce the accessories, e.g. 'smoke' drill, R/T broadcast, and where to incorporate large power changes for added effect. It is not usually recognised how much additional workload these extras impose.
- Select one or two reliable ground critics to assess the practice sessions and ignore most other comments.

Additional Safety Factors

These are some additional safety factors other than those already discussed, which should be observed.

- Never introduce a new manoeuvre into an old sequence without adequate practice at a safe height.
- The sequence must be orientated to ensure complete spectator safety.
- Always have an alternate bad weather display which is just as well rehearsed as the main one. The CT4 A/B Airtrainer display requires only 2500 feet cloud base and 5 km visibility, hence if the weather is worse than this a display of any kind is unlikely.
- Never violate any of the safety parameters or limits of your authorisation.
- Whenever rolling inverted, select a small positive pitch attitude first, so that the roll to the inverted attitude can be accomplished solely with aileron leaving the maximum of forward control column movement to correct for an error of judgment.

Conclusion

A guaranteed safe display depends on a thorough knowledge of the performance and behaviour of your aircraft, the strength of character to resist the urge to impress, and a truly professional attitude at all times.

Towards Safer Display Flying

Based on an article by Wing Commander N T Raffin AFC - Royal Australian Air Force

Introduction

Since the barnstorming days of the 1920's a wealth of experience must have been gained by pilots taking part in air displays. Nevertheless, a pilot faced with training for an air display today, has no reference sources for preparation but must rely on their own ingenuity in training themselves. This very specialised form of flying demands more than a trial and error approach. In fact, display flying requires a professional approach including a careful study of all factors involved.

Accidents that have occurred during practices and displays in the RAAF suggest that some pilots have failed to adopt a professional approach. The most probably reason is the absence of suitable reference material from which embryo display pilots can obtain guidance on the problems associated with display flying. To this end this article will highlight the problems associated with display flying and in addition will suggest the need for a changed outlook on display flying. Both the highlighting of the problems and the need for a changed outlook are necessary in adopting a safer approach towards display flying in the RAAF.

Approach to the Task

In RAAF displays, the audience is the taxpayer and I recommend this factor be given paramount importance by all pilots throughout display flying. I cannot think of any RAAF display in which a pilot has had to perform for an expert audience. I am not suggesting that the connoisseur should be ignored but what I do suggest is that a well-balanced display should consist mainly of manoeuvres that are pleasing to the crowd and not necessarily difficult to perform.

Far too many display pilots in the RAAF are more interested in comments by their fellow competitor or squadron mates, than in what pleases the public. The inevitable practices performed at their home base are conducive to the pilot attempting to impress the wrong audience. Pilots must be aware of this factor and treat criticisms by fellow pilots accordingly.

After the 1967 Paris Air Show an author wrote 'Solo low altitude passes generally are done between 50 and 100 feet altitude – though may get as low as 30 feet'. I do not intend in this article to quote Air Staff Instructions but I must mention regulations in general. From my own experience, the above quotation would be accurate as most displays in Europe are flown at altitudes that would not be tolerated in the RAAF. In some cases the pilots are breaking regulations and their actions are condoned. Competition between rivals is the cause of the low passes but I am sure very low passes gain nothing. Firstly, the front row of the audience will be the only persons that will see them and secondly, regulations must be obeyed if they are to achieve their purpose. I will mention lowest altitudes again in this article when referring to presentation and will restrict my comments here to the obedience of regulations. After the fatal accident in a Mirage at Williamtown last year additional regulations were imposed on all pilots displaying Mirage aircraft. The additional regulations included no low level aerobatics. I remember one particular pilot who performed a 'crowd grabbing' display by capitalizing on speed and noise. At the end of his display however, the pilot felt disappointed because he was not able to do his aerobatic routine. He should have felt professional satisfaction as he had already achieved the aim of his display, to please the crowd.

To quote AFO's, ASI's and other regulations in the briefing for an airshow is not always sufficient. Follow-up action against any rebels after the airshow is the surest way of ensuring that the rules will be obeyed. If one pilot is allowed to break the rules, others will follow and this approach will only end in disaster. Finally on this point, a pilot cannot do a better show than his authorising officer will allow – nor should the authorising officer expect any better than they have authorised.

Presentation

Having decided that the audience will be the general public and that all particular regulations in force have to be obeyed the next step to be considered is the planning of the display. No one can quote basic steps to follow that would apply to all aircraft but each display should have a central theme. Experience on type can help to decide what characteristics of the aircraft can be best displayed. Particular characteristics would be the operational role, the range of speed or the manoeuvrability of the aircraft. Whatever characteristic is selected, this must become the highlight of the display and other sequences are secondary. Equally important the routine must be worked out and cleared by the authorising officer before any practice is attempted. In addition, whenever a change in routine is contemplated, it is the responsibility of the pilot to inform the authorising officer before the change is attempted. Any other approach is unacceptable in display flying. The authorising officer should clearly define the limits of the authorisation and follow progress in subsequent practices.

I mentioned earlier in the article the subject of the lowest height. Ideally the aircraft should be presented to the audience so that it can be viewed at an angle of approximately forty five degrees. The angle should never be as low as zero degrees nor should it be as high as ninety degrees. In the first case the aircraft is too low and in the latter one of the rules would be broken by flying directly over the crowd. If the aircraft is to be viewed at forty five degrees, at the lowest altitude the aircraft will be closest to the crowd and at the highest altitude the aircraft will be furthest away. In a manoeuvre that involves a change in height the best presentation has be considered. For example a looping manoeuvre can be presented closer to the crowd by presenting the loop parallel to the crowd front than can the same manoeuvre presented head on.

Presentation is the difficult part of display flying and must be considered during planning as well as in the execution of the sequence. A useful hint is always using the crowd front as the only reference during the presentation. Other check points will vary with wind and of course are of no value on a different airfield. The presentation of each manoeuvre has to be planned and each manoeuvre has to be joined very carefully into the sequence. Some pilots draw an accurate plan of their display to assist in presentation but this cannot always be done as the wind can negate the use of a plan in very light aircraft. Wind effect does make accurate presentation a difficult problem in all aircraft and must be considered throughout the display to ensure that the aircraft does not drift away from the display line. Frequent practices in all wind conditions will provide invaluable experience for the display.

Variation within the sequence is also important presentation. A sequence becomes a monotonous after three or four minutes of the same type of manoeuvre. However, variation must be practicable. A high speed run immediately after a slow fly past may not be practical in some aircraft but a high speed section followed by a low speed and then acceleration could be a way of obtaining variation. In general a sequence should last between five and fifteen minutes depending on aircraft type, but regardless of the length adherence to programmed time during displays is most important and training should not ignore this part.

Allowances must be made during planning and final practices for other variable factors that can occur on the display day. Of these factors, one can prepare for bad weather by knowing what weather conditions are required for the display. Under no circumstances should a display be attempted if the weather is worse than those conditions. A bad weather routine can be planned and practiced along with the normal routine. It is a good idea to have the two routines following similar patterns for then presentation will be simplified. Safety factors should be built into the routine to safeguard against the many problems that can occur. A spare aircraft should be available and ready to start in case of last minute unserviceabilities and preparation can also be made for unfamiliar air traffic control procedures. Every factor that is considered during planning is insurance against the unforeseen factors that always seem to appear on the display day.

So far this article has dealt with some of the factors that must be considered in planning and presenting an air display and has given some idea of how to approach the task of display flying. A good display is not one that is achieved by a trial and error approach. A good display should be the result of careful planning and a comprehensive training programme. The training programme will depend on the preparation time available, flying hours allotted for practices and time that can be spared from other essential tasks. Results should not be expected in the first week. Practices should be commenced at a reasonable altitude and only when proficiency is gained at that altitude should the height be lowered. A pilot must feel confident with the display before it is presented over the airfield for authorisation to a lower level. This is an important time to remember that the aim of the display is not to impress fellow pilots.

Analysis of Accidents

Generally the RAAF displays that I have seen have been of a very high standard. Apart from the occasional pilot who was obviously performing for the wrong audience, RAAF pilots generally show a very good appreciation of display flying. The RAAF's capability and polish have been demonstrated in a professional manner and I am sure displays have done much to enhance the Service's and the Nation's prestige.

However the fact that accidents do occur shows that some pilots do not consider all the factors involved. Therefore, let us look at some of the accidents and trace the factors that were neglected.

On the 18th September 1955 a Vampire crashed during a demonstration at Pearce. The pilot had been briefed for high speed runs which were to complete the flying display. During the first run which was being made at approximately 100 feet the pilot attempted a low level roll and the aircraft crashed. The pilot had been assessed as above average and had over 1500 hours experience. He was considered by his fellow pilots as being quite proficient in aerobatics but not the type who would attempt a risky low level roll. The only satisfactory explanation for the pilot's attempting such a manoeuvre could be that the pilot acted on the spur of the moment.

This pilot acted on a very natural impulse but even if the roll had been successful he would have faced serious charges back on the ground. This in itself is sufficient to deter most pilots from such an action. At the same time similar temptations will face other pilots during displays. That sudden impulse to go a little lower or to pull that extra 'G' can very easily end up with the same result.

The importance of staying rigidly to a planned and practiced routine can be exemplified by the accident involving a Cessna aircraft at Toowoomba on 15th November 1965. The pilot of this aircraft was well rehearsed in his routine but on the day appeared to substitute a stall turn for a wing over. There was insufficient height to recover and the aircraft hit the ground.

There seems little purpose in practicing time and time again a set routine if on the day of the display one forgets all the hard work and starts to ad lib. One might as well save the time and effort and 'play the display off the cuff' as the pilot in the Vampire did. The result will most likely be the same in both cases.

The court of inquiry into the fatal accident involving the Red Sales Aerobatic Team on 15th August 1962 highlighted a number of factors to be considered during the training of an aerobatic team. Many of the recommendations have been adopted and been used during training of other aerobatic teams since the accident. In my opinion one very important factor about this accident was that the leader had been newly appointed and he had adopted the previous leader's display. I think it is very wrong to attempt another person's routine. The development of a routine is an involved process and is part of learning the sequence. Each display is designed….

Unfortunately the material I sourced for this article ended there. If anyone has the rest of the original article I would be very interested in seeing it. Thanks. I hope these notes and articles were helpful to you. Safe flying.