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focus

ON COMMERCIAL AVIATION SAFETY

WINTER 09

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avoiding communication error top ten tips for controllers

Communication error is the biggest causal factor in both level busts and runway incursions in the UK. The following tips for controllers will help improve RTF standards in UK airspace:

- Use clear and unambiguous phraseology at all times; challenge poor rtf.
- Try to avoid issuing more than two instructions in one transmission.
- All frequency changes should be kept separate from other instructions whenever possible.
- Use standard phraseology in face-to-face and telephone coordination.
- Monitor all read-backs; try to avoid distractions - especially the telephone!
- Aim to keep RTF delivery measured, clear and concise, especially when the frequency is congested. But, if it's urgent, sound urgent!
- Always insist on complete and acurate read-backs from pilots.
- **W**rite **A**s **Y**ou **S**peak, **R**ead **A**s **Y**ou **L**isten (WAYSRAYL).
- All executive instructions relating to headings ending in zero MUST be followed by the word 'degrees.'
- If you are unsure, always check!

Communication Error - An industry-wide campaign to improve RTF standards supported by:

CHIRP

Civil Aviation Authority

Contents

The Official Publication of THE UNITED KINGDOM FLIGHT SAFETY COMMITTEE ISSN: 1355-1523 WINTER 2009

FOCUS is a quarterly subscription journal devoted to the promotion of best practises in aviation safety. It includes articles, either original or reprinted from other sources, related to safety issues throughout all areas of air transport operations. Besides providing information on safety related matters, **FOCUS** aims to promote debate and improve networking within the industry. It must be emphasised that **FOCUS** is not intended as a substitute for regulatory information or company publications and procedures.

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Front Cover Picture: BLinks first Citation Mustang G-FBLK, on the ramp at Farnborough Airport.

Threats and Challenges to Aviation Safety

I am writing this editorial for the winter edition of FOCUS on the aircraft returning from this year's International Aviation Safety Seminar where we have considering the current state of civil aviation safety and, in particular, what safety professionals should be tackling next to get the air accident statistics from off the plateau on the graph and moving downwards once again. The conference was presented with a wide variety of views and solutions, some old and some new, both in conference session and in the many sidebar discussions which contribute to additional value to these sorts of gatherings.

We were fortunate and fascinated to be hosted by the Civil Aviation Administration of China (CAAC) who fielded several senior speakers who were able to provide a glimpse into the impressive progress made in air safety by their country, despite the challenges driven by an incredible expansion in their commercial transport sector of over 17% year on year and a mass migration from old Eastern Block technology aircraft to modern Western fly-by-wire aircraft bristling with extensive automation. Equally impressive, the Chinese are opening a new airport every 4 months up until 2020! But in meeting this incredible pace of change, to their great credit they have done so without a single accident in the past two years or more.

The philosophy expounded by the Administrator of the CAAC was interesting: the more you talk about your achievements, the less you achieve and the more you talk about your problems, the fewer problems you encounter! Paradoxically, another IASS session reflected upon the impact on safety, both actual and potential, of the recession generally and the serious downturn in the industry in the western world in particular. Unsurprisingly, the tragic Colgan accident in Buffalo earlier in the year was a major topic of conversation and promoted training and fatigue to the top of the agenda particularly amongst the large US contingent.

Another major theme of the conference was the introduction and implementation of Safety Management Systems across the globe. It is clear from evangelists and sceptics alike that the industry and its leaders are placing great store on this approach to deliver the next major step improvement in aviation safety. There is a significant body of opinion that believes this to be the only game in town as far as getting the accident rate moving down from the plateau of recent years. However, it was pleasing to note that the other side of the SMS coin, the reporting culture required to support it, was placed firmly on the table by several speakers, including myself. An effective reporting regime is absolutely fundamental to enable a productive SMS to develop and prosper, but this especially difficult issue does not enjoy anything like the same level of consideration or discussion as the SMS process itself.

Development of an open reporting culture cannot be discussed without addressing the threats to its success. One presenter, who is a leading Barrister in the UK specialising on corporate manslaughter, made it perfectly clear that as far as special pleading for the commercial transport sector to be protected from criminal prosecution was concerned, the Genie was well and truly out of the bottle! But he then went on to emphasise that, after an accident involving death or injury, the target for such prosecutions was not necessarily the pilot or engineer, but the leadership of the organisation employing them. In most criminal cases in the future, it would be the failure of the organisational support to the employee which would be cited as the main contributor to the event. Therefore, it would be the chief executives and accountable managers of these failing organisations who would be brought to book. Furthermore, the rather restrained and derisory fines of the past, which used to be comfortably met without large companies breaking step, are now being changed in law to amounts of up to 10% of annual global profit for the worst offenders.

Our major concern now must be that criminalisation will increasingly feature alongside internal company discipline and anti-trust laws denying airlines from exchanging information on the list of real threats to any positive reporting culture. Certainly in the UKFSC, the concern must be that any threat to free and open occurrence reporting could seriously undermine the vital contribution to aviation safety enjoyed in the UK over the past 2 decades. Arguably, with the implementation of SMS now finally taking shape, this could not have happened at a worse time since the gathering and analysis of occurrence reporting data is the very life blood of a successful SMS. Without effective and free occurrence reporting within a confidential wrapper, proactive action to deny accidents and incidents is dead in the water!

So what must be done to maintain and encourage occurrence reporting in the UK, and beyond, in light of this increasing threat. One thing is for certain; the idea of commercial aviation being placed above the law is a non-starter. The challenge for all aviation safety professionals is to get engaged with the legal profession and the judiciary at every opportunity, to explain the essential contribution of occurrence reporting and safety information sharing to improving future aviation safety. Equally, we must explain that whilst negligent and wilful misbehaviour must be pursued through the court, the careful handling and protection of aviation safety data is required to reassure those reporting their honest and genuine mistakes, to which no human being alive is immune, can do so without fear of action being taken against them.

But that is not all we must do. There is an equally important challenge. We must also engage with the responsible media and seek the trust of the general public. They must be educated to understand that only through affording effective protection of safety data and information and a confidential exchange between airline operators, regulators and service providers can the lessons be learned for the overall well-being and safety of the public into the future.

Winter Thoughts

by Capt. Tony Wride, Monarch Airlines

Whilst sitting in my room on a tropical paradise island in the middle of the Indian Ocean with the weather outside clear and very hot I decided to write this article. Three days ago when I flew the Company A330 into here it was a different story completely with strong blustery winds, heavy rain and lots of cumulo-nimbus clouds around, which at the end of a 10 ? hour flight certainly concentrated the mind! At one point it was looking likely that we would have to divert as the wind, which was straight across the runway, had increased to over 33 knots and the visibility decreased to 500m in heavy rain. Fortunately a well timed gap appeared and we were able to land with only a 15 knot crosswind on a runway that was not completely flooded. The cyclonic conditions persisted for 2 more days, in fact it actually got worse which caused a number of aircraft to divert, and it's only now that the wind has abated and the sun has come out.

Pilots constantly face the challenges that 'Mother Nature' throws our way and as we all know some of those challenges can be extreme. I watched an 'Air Accident Investigation' programme recently that showed a few serious accidents that had been caused by severe weather. The first was a DC9 that crashed in 1977 when it flew through the middle of a thunderstorm and ended up with both engines flamed out. The crew very nearly made it down in one piece having landed on a highway but unfortunately the aircraft broke up when it hit a power line and several obstructions. In another incident a DC10 landing in Texas encountered severe windshear as it passed through a microburst on short finals resulting in a crash and a large number of fatalities. Both of these incidents were as a direct result of the severe weather associated with thunderstorms a very common occurrence in the hotter parts of the world and not that uncommon in the UK.

As we head into winter there are other weather challenges that not only confront the pilot community but also challenge everybody working to support the aircraft, particularly on the ramp. Winter brings a whole host of weather problems from severe gales, to fog, ice and snow. The whole aviation community suffers from the effects whether you are sitting in Air Traffic Control trying to work out how to keep your airport operational or working on the ramp loading the bags into an aircraft in freezing conditions and suffering from the effects of the cold. The pilots face the challenge of making the decision, based on well proven techniques, on whether it is safe to take off or land in the prevailing conditions. But the pilots rely heavily on so many other people doing their job correctly. The team that carries out the aircraft de-icing prior to departure, the team doing the runway snow clearing, the person doing the check on the runway condition, and the person that did all the calculations for the contaminated runway performance to name but a few. All of these people are vital and any one of them could cause an aircraft accident if they don't perform their duty diligently.

You may remember the tragic crash that happened in Birmingham a few years back to a private jet that had not been de-iced correctly, in fact I believe it hadn't been de-iced at all. The aircraft tried to take off with ice still on one wing destroying the lift characteristics of that wing whilst the other wing had been de-iced as a result of environmental factors. The different lift characteristics caused the aircraft to roll shortly after getting airborne with fatal consequences. The bottom line is that no aircraft should try taking off with anything on a wing, or other control surfaces, that could affect the lift generating properties of that surface. That's easy I hear you say we just have to make sure we always thoroughly de-ice the aircraft. However, in this climate of all airlines trying to cut costs are we at risk of some corners being cut?

You only have to read the papers to hear that some of the big airlines are loosing in excess of £1 million per day whilst the smaller airlines are also making a loss. De-icing is a costly exercise and airlines are actively trying to find cheaper suppliers in an effort to reduce the bottom line costs. True, the Tony Wride De-Icing Company Ltd using a 25 year old American built de-icing truck with a team that were hired yesterday and underwent a 1 day de-icing course, could spray de-icing fluid onto an aircraft for 25% less than the well established professionals, but would that aircraft be properly de-iced? In fact in most cases the aircraft would be de-iced sufficiently but the risk that on occasions an aircraft could be de-iced incorrectly is greater.

Experience in any job, be it as an Air Traffic Controller, a Pilot, or a de-icing operator has an unquantifiable value and it could be argued that the experience helps to reduce the risk. Equally, correct training and a robust, active Quality System also helps reduce the risk. Now try selling that to a senior manager who is looking at the bottom line on everything and deals in numbers not unquantifiable values! Add into the equation a general public who expect to fly several thousand miles in a seat with loads of leg room, get free drinks and Master Chef quality food all for the equivalent of a night out for 2 at a MacDonald's restaurant and you wonder how on earth the commercial aviation industry can survive safely.

Winter operations requires everybody to remain FOCUSED, (no pun intended but it is a good name for a Safety Magazine), on their particular job despite the adverse conditions that they may have to work in. Everybody needs to be professional and that may mean spending that little bit of extra time familiarising yourself with the relevant information on Winter operations so that when it comes you are fully prepared. Those people who are out working in the adverse conditions need to be looked after in terms of providing correct clothing and everyone needs to be more understanding if something takes a little longer to do.

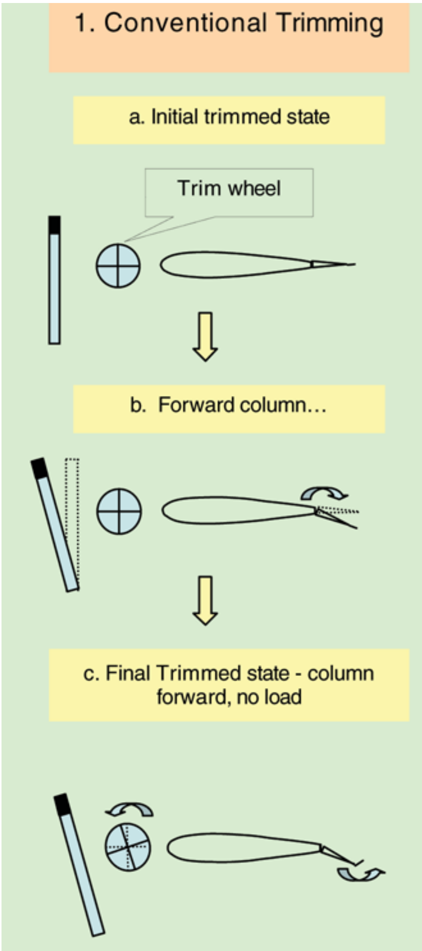
As an industry we cannot afford to cut corners and perhaps now is the time that we actually should be re-educating the general public on the costs involved in flying an aircraft safely.

Do you *really* understand how your trim works? Many do not, and why it matters.

by Alex Fisher - GAPAN

Picture yourself in a conventional airliner, say a 737 of any generation. You have to do a low level go-around, perhaps because your fail passive Cat III has just failed, er, passively. You apply GA thrust, and the aircraft pitches up. If you are low enough, you may already have some extra helpful nose up trim applied thanks to the 'design feature' that ensures that in the event of AP failure at low level, the aircraft pitches up not down, and so a few units of nose up trim are applied late in the approach. Your speed is low, about Vapp and the thing is pitching firmly upward. You need ample forward stick/elevator to restrain it. You don't want to carry this load for long so you retrim. Question: if you run the trim forward while maintaining forward pressure on the wheel, what happens? Hands up all those who think the load reduces to zero. I see a lot of hands. My unscientific polling to date suggests that just about everyone is convinced that this is what happens, but it doesn't.

Nearly everyone of my generation trained on a Cessna 150 or a Piper PA28. You fly those aircraft by putting the attitude where you want it, holding it there by holding the stick rigid and retrimming until the load goes to zero. In fact if you didn't do that, but were too quick and started trimming before the aircraft was stable, the instructor would exhibit a severe sense of humour failure. Let's just consider what is going on. Starting from an 'in-trim' state, fig 1(a) (just for illustration I have shown it as everything in the middle, but obviously this isn't essential to the argument); then, fig 1(b), the column is held forward moving the elevator down. Moving the trim wheel, fig 1(c), in this case moves a trim tab which relieves the control load until it goes to zero; the column can again be released, and it stays forward where you left it. So in this scheme, the control column stays forward for high speed and back at low speed. Although I have shown a tab operated system, the same result can be achieved without a tab by means of a spring in the control circuit or by altering the neutral point of the feel system. Aircraft as diverse as the Tiger Moth, the L1011, and Concorde fly this way.

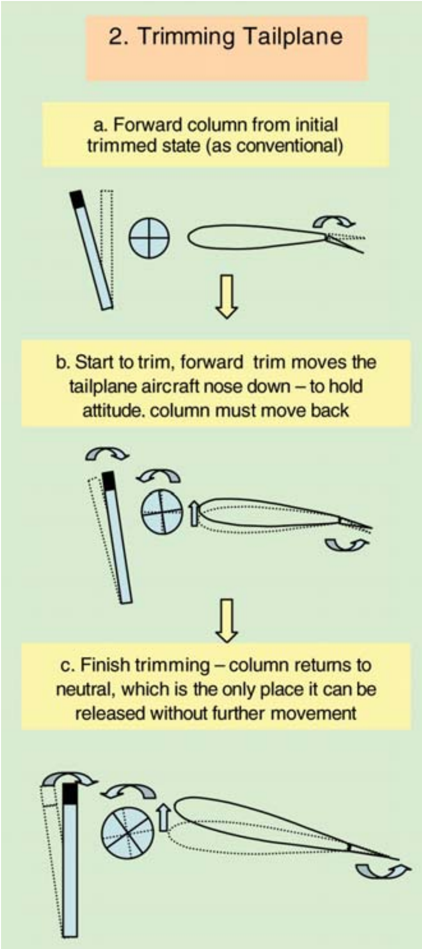


Now there is another class of aircraft that works totally differently. This group includes most conventional transports, and even the non conventional A320 series in direct law. In these, the tailplane is controlled directly by the trim system, while the control wheel controls only the angle of the elevator relative to the tailplane. Now starting again from the out of trim state we started from above (see fig 2), as the nose down trim is applied, the tailplane starts to move leading-edge up. In order to keep the force contributed by both the tailplane and elevator constant (i.e. to maintain attitude), the elevator angle has to be reduced as the tailplane incidence increases (fig 2b). To do this, the column/wheel has to be moved back towards neutral. When the operation is complete, the column/wheel is back in the neutral position, which is the only place it can be released without further movement (fig 2c); its position does not indicate the trim state of the aircraft. For years Boeing manuals have said flatly that the control wheel cannot be moved opposite to the direction of trimming motion (the trim motors cut out if it is)…. Wrong, it can, and indeed has to, be moved in the opposite direction every time the trim is used; the action is achieved by just relaxing the pressure on the column and allowing to drift back to neutral. It is true that if pressure is applied to the column opposite to the direction of trim, then the trim cuts out.

This behaviour (column always returns to neutral regardless of speed) is not necessarily limited to aircraft with trimmable tailplanes; for example, if the column operates a servo tab while the trimmer moves a separate trim tab, the effect would be the same (I believe the 146/RJ series works this way). Doubtless there are other combinations too, you really have to study the systems carefully.

When I converted from a 'conventional' trimming type (Trident) to a separate trimming tailplane (757), not a word on this subject appeared in the training notes, nor was anything ever said by any training captain. Many years later I did write something for the company Magazine and generic training manual, but apart from one reprint in the Far East it has not been widely circulated. So how do people go through an entire career without realising things have changed from the way they were first taught? I think it is because mostly any column movement is followed immediately by small movements of the trimmer, so large loads are never allowed to develop and the reverse column movements are virtually imperceptible. In 'normal' flight operations, movements in pitch are mostly quite small, apart from two: rotate and go around; the latter is relatively rare, while the former is transitory (if the take-off trim is roughly right (!) you can relax the load after lift off with the aircraft roughly at the right attitude).

So why does it matter? The chances are you will fly more smoothly if you understand what is going on, but there are three broad categories of error which are likely if these subtleties are not understood, I will cite examples of each.



2. Trimming Tailplane

1. Failure to understand the trim function (the process described earlier) itself. This isn't disastrous. Most pilots are in this category, but they cope well anyway, by simply flying on the trim. This isn't how they were taught, but, well, it works. It begins to matter when the trim changes are large. I have watched, in the simulator, a 737 go-around from a Cat lll fail passive approach (as described above) with its marked pitch up; HP kept his arms locked forward to contain the attitude whilst simultaneously running the trim forward with the thumb switch. I am sure he was expecting the trim to reduce push needed and he either didn't know, or had forgotten, that it wouldn't. We duly pitched straight back quickly into the ground as the tailplane incidence 'bit'. I can't cite with certainty any accident that has been caused by doing this, but I strongly suspect this was a factor in the infamous Icelandair upset event at Oslo The aircraft went quickly from +20 deg to -40 deg and was only saved from a CFIT by a 3.5g pull up, bottoming out at 360ft. Sadly, the report does not discuss the control inputs, nor does it contain any FDR traces, so this trim confusion explanation must remain speculation. I would be astonished, however, if there weren't more examples of this error, particularly in unfamiliar situations.

2. Failure to realise that the tailplane, commanded by the trim system, is a totally independent pitch control; it will be available if the primary control is inoperative or ineffective. But if you only think of the trimmer, wrongly, as a column-load reduction device, you may not think of its other use when needed. The following examples illustrate the point; I am certain of the first, the others must remain speculation in the absence of evidence.

3. Some all moving tailplanes are trimmed conventionally – the Trident's was commanded by both the column and the trim wheel; the 'elevator' was a geared tab (reproduced with

(a) 747-400 Take-off incident . Just after lift off the aircraft suffered an elevator hardover, uncommanded full nose down movement of one elevator; the pitch attitude began to reduce. The crew's reaction not unreasonably was first to pull harder, then a lot harder, which succeeded in preventing an immediate accident, but cannot be said to have truly regained control. The anomaly lasted about 8 secs until a spike in the hydraulic pressure during the gear raising sequence allowed normal control to be resumed. No one thought of just blipping the trim button to restore order. Did thinking of the trim as merely a load reducer blind them to the simple solution? The incident report does not mention the alternative control available and does not discuss that part of the pitch control system at all.

(b) THY DC-10 crash at Ermenonville in 1974. This was caused by an improperly secured cargo door which blew off; the floor above it collapsed due to the pressurisation load, disrupting the controls and injecting a nose down elevator input. Rumour, I admit quite unsubstantiated, has it that it could have been flown on the trim as there was still hydraulic power to the tailplane (350 casualties).

(c) The BAC 1-11 flight test super-stall . There was insufficient elevator to recover, but the FDR trace shows that no attempt was made to adjust the tailplane which would have been more powerful. It is pure speculation now after 40 years, but it is an intriguing thought that it might have helped. There would certainly have been no similar possibility for the Trident that was lost during a pre delivery test flight a year or so later as the trim and

4. Trimming tailplanes aren't confined to the jets – this Piper Cub has one, as shown by the slot near the tailplane l.e. which provides access to the actuating link

column both operated the tailplane and its geared elevator together (see fig 3).

3. Failure to appreciate that loss of control in pitch might be due to the independent operation of the trim system. Several well known pitch upsets to A300s and A310s (see for instance the TAROM upset at Orly Sep 1994 , and the A300 at Nagoya, April 1994) have been caused by a tailplane movement which was not fully appreciated by the crew, and was all the more insidious precisely because there was NO change to the load on the column. This is the reverse of the situation in (2). None of these occurrences were technically trim runaways, so there were no warnings and no indication to the crew from the feel of the column. The first incident started with the flap overspeed protection system (the designers obviously thought that putting in nose up trim would reduce the speed… well it will if you understand totally what is happening and don't override it); the second, a fatal accident, started with an inadvertent, and probably unnoticed, GA selection.

A system where there are two independent means of control, has obvious safety benefits, but it also has pitfalls if it is not fully understood. The lack of importance given to the trim system in training seems extraordinary. I recall asking for TC guidance during my 757 conversion, to be told that there was no difference to previous types; when I finally convinced His Eminence that there was, he blustered that it didn't matter. I can find no relevant discussion in my edition of the Bible, Handling the Big Jets; I guess the Test Pilots just cope with anything they come across without preconception, and perhaps don't realise how much baggage the rest of us carry from our basic training. Accident investigators would also do well to ask themselves more often just how the unfortunate pilots had been trained, and cover the likely rationale for the control inputs in their reports. The illustrations I have used are obviously very rare events, so it is very unlikely that any one reading this will ever face their like. Engine cuts at V1 are pretty rare too, but they get a lot more exposure in training than the basic control functions, odd, isn't it.

Postscripts

This article was written for the UKFSC Focus magazine in late 2007. Since then there has been a spate of accidents and alarming incidents in which 'tailplane ignorance' has played a part. The 737 accident at Amsterdam, an as yet unpublicised 737 incident in the Far East, and the Perpignan A320 crash all, in different ways, involved a stall and unsuccessful or botched recovery. The shared feature is that in each case the tailplane had wound itself to a fully (aircraft) nose up position, as in (3) above; the combination of pitch up, due to full power, and low speed, meant recovery was probably impossible using elevator alone, to get the nose down meant moving the tailplane back to a more normal position, which means running the trim forward. The A320 accident appears to be the result of an improper flight test, but the two 737 cases occurred in normal line flying and illustrate how important it is to understand what the tailplane is doing, and how easy it is for it to finish up somewhere unexpected; in both these cases the trigger was an unnoticed Autothrottle failure on approach, the speed fell and the autopilot duly trimmed progressively further back until it reached full nose up and quit; recently, April 2009, the UK AAIB published a report into yet another 737 near stall and upset and made the following recommendation:

Safety Recommendation 2009-045: It is recommended that Boeing clarify the wording of the approach to stall recovery Quick Reference Handbook Non normal Manoeuvres to ensure that pilots are aware that trimming forward may be required to enhance pitch control authority.

The report contains the relevant Boeing Ops Manual pages in an appendix, including this:

To recover from a stall, angle of attack must be reduced below the stalling angle. Nose down pitch control must be applied and maintained until the wings are unstalled. Application of forward control column (as much as full forward may be required) and the use of some nose-down stabilizer trim should provide sufficient elevator control to produce a nose-down pitch rate. It may be difficult to know how much stabilizer trim to use, and care must be taken to avoid using too much trim. Pilots should not fly the airplane using stabilizer trim, and should stop trimming nose down when they feel the g force on the airplane lessen or the required elevator force lessen. (my emphasis)

The forces won't lessen by themselves, so that last remark puzzles me – does the writer think that the column load will go to zero as the trim is run forward? It can certainly be read that way, but if you have understood the rest of this article you should be able to understand the subtle coordination required to bring the tailplane safely into play without creating a worse nose-down problem. But you will also appreciate that the bigger danger at the moment may be that too many pilots don't think about trimming at all in this situation.

A Spanner in the Works?

by Ian Hay - Coplan Limited

It's a simple question which I ask when visiting maintenance organisations:- "How can you be absolutely sure that all the tools you used on that airframe today are back in your toolbox?"

The answer however, is not so simple and is quite disturbing.

Most aircraft and helicopter maintenance operations allow (and in some cases encourage) uncontrolled tooling to be used on airframe and power plant maintenance. This is justified with a variety of statements including:-

- Our engineers have their own tooling.
- It's not workable.
- It costs too much.
- It's not a legal requirement.
- Our engineers are careful.

Uncontrolled tooling is defined as tools that are unaccounted for, either supplied by the company or brought into the hanger by engineering staff and usually stored in a personal toolbox with hundreds of other tools. The problem is that if one tool is missing (left in the airframe) the engineer/fitter is unlikely to know and this 'lost tool' has the potential to cause a catastrophe!

The simple solution is to use a tried and tested tool control strategy to ensure ALL tools are accounted for at any given time during maintenance. Simply housing the engineers' and fitters' tools in twin coloured foam creates a situation where just a glance at the tool box can confirm that all tools are present and accounted for as any missing tools would be highlighted by the bright bottom layer of foam. This system is called Visual Tool Control VTC and is a simple and economical first step towards full tool control.

Once the decision to 'control tools' has been taken the whole maintenance operation instantly becomes safer, all unauthorised tools are removed from the hanger and all the remaining tools are listed in a tool control manifest and then housed in VTC foam (even the engineers own tools can be authorised and integrated into the foam – excuse number one dealt with!).

Many organisations also have a variety of specialist tools usually kept in the bonded store, these tools should also be housed in VTC foam in order to establish tool control, another benefit of using VTC foam is that it protects whatever it holds and with very expensive aircraft tooling that's reassuring. VTC foam comes in a wide variety of colours which can be used to further enhance safety and efficiency. For instance it can be used to provide a visual difference between AF and metric tools or to define tools assigned to a particular job or airframe. The foam is 'closed cell' so it does not absorb liquids and is also resistant to all hydraulic fluids including Skydrol.

Tool control is vital to the safe and professional maintenance of all aircraft. It is defined by the

CAA, FAA and EASA as the responsibility of the maintenance organisation's management to ensure that acceptable standards and operating procedures are put in place. In these days of corporate manslaughter and litigation any company not enforcing a well thought out tool control policy is leaving itself very exposed. Imagine an accident (fatal or otherwise) where a 'lost tool' is proved to be the cause; the subsequent accident investigation would soon focus in on the companies standard operating procedures for tool control with devastating consequences.

*In fact just such an accident occurred at Aviano AFB in Italy in 2007 where a US Airforce UH-60 Blackhawk helicopter crashed killing six people and injuring five more. The accident investigation concluded the crash was either caused by control failure or a foreign object lodged in the controls. The families have now filed a law suit against the maintenance contractor for negligence.
*Source: Stars & Stripes, October 18th 2009.

Cost is always an issue and is the most common excuse for doing nothing, in fact I was recently told by a major helicopter maintenance organisation within the UK 'We love the idea but until there's a fatal accident and we're forced into it, we won't buy it!' I was simply stunned. However reality is often different to perception, the truth is, tool control is very inexpensive especially when weighed against inefficient working practices (looking for lost tools), delayed aircraft release due to tool loss (airlines) or the defence of a law suit following an accident attributed to tool FOD.

Tool Control – When you think about it, it's common sense.

Flying into the Sea

by Linda Werfelmen

The crew of a CHC Scotia Aérospatiale SA 365N Dauphin 2 lost control during a night time approach to a gas platform in the Irish Sea, overflying the landing site and striking the water. The helicopter disintegrated on impact and sank in the Dec, 27, 2006, crash, killing the two pilots and all five passengers.

The U.K. Air Accidents Investigation Branch (AAIB), in its final report on the accident, cited three contributory factors, including the lack of a "precise" transfer of control from the copilot to the commander after the copilot lost control of the helicopter during the approach in poor weather conditions. Four seconds elapsed after the copilot's request for help before the commander took control of the helicopter, the report said.

"The commander's initial actions to recover the helicopter were correct, but the helicopter subsequently descended into the sea," the report said.

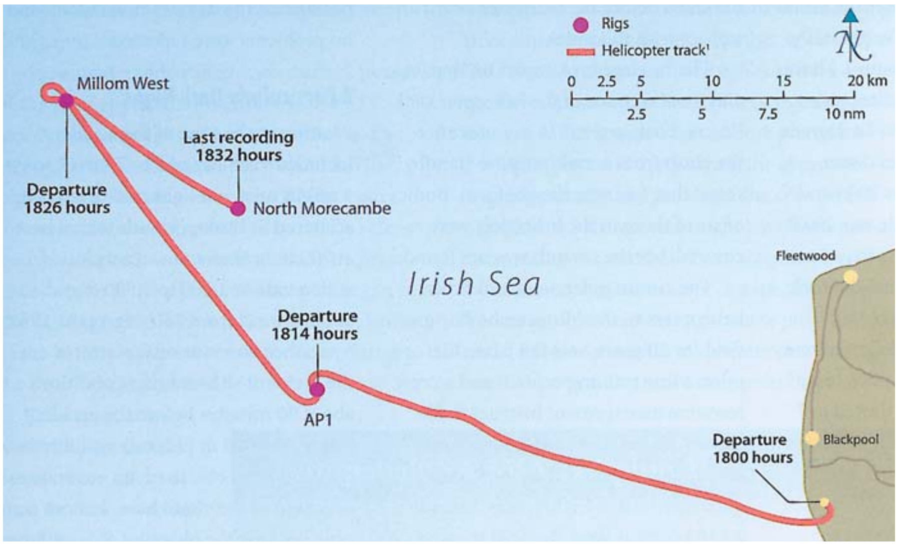
The AAIB also cited "the approach profile flown by the copilot, [which] suggests a problem in assessing the correct approach descent angle, probably... because of the limited visual cues available to him."

The third contributing factor was the company's failure to use "an appropriate synthetic training device," although one was available, the report said. "The extensive benefits of conducting training and checking in such an environment were therefore missed."

The Report said that the helicopter had departed at 1800 local time from Blackpool Airport, a base for helicopter support for gas operations in the East Irish Sea, for a planned eight-segment flight to offshore gas production platforms operated by Hydrocarbon Resources Limited (HRL).

The crew had flown a similar multi-segment flight earlier in the day and had completed the first two segments of the accident flight without incident. As they began the third segment, from the Millom West platform, five passengers boarded. Plans call for a seven-minute flight to the North Morecambe platform to pick up a passenger and some freight before continuing to another platform.

The helicopter left Millom West at 1826, climbed to 500 ft and accelerated to 125 kt. The automatic flight control system was engaged, and the helicopter was in the normal stabilization mode for flight, the report said. The commander, the pilot not flying, confirmed that lights on the North Morecambe platform were properly illuminated.



Route of Accident Flight

Note: 1. The helicopter's track was derived from its combined voice and flight data recorder.
Source: UK. Air Accidents Investigation Branch

"Shortly after the 4nm [7km] GPS [global positioning system] call made by the commander, the crew became visual with the rig, and the copilot said, 'I got the deck now,'" the report said. "Allowing for the speed of the helicopter at the time, this equates to a visual range of about 6,800m [4mi]. The commander then completed before-landing checks, which including arming the floats."

The helicopter was at about 270 ft when the copilot announced his sighting of the platform but climbed to just over 400 ft and then began another descent.

The helicopter's combined voice and flight data recorder (CVFDR), which records five hours of data and one hour of audio from the commander's, copilot's and cockpit area microphones, at 1832:21, recorded the commander saying, "You get no depth perception, do you?"

The copilot replied, "Yeah, not on this one, not tonight, no." During this part of the approach, there were "steady increases in the collective, tail rotor input, cyclic pitch and cyclic roll input." And radio height decreased, then increased, the report said.

At 1832:33 – with cyclic pitch and roll inputs increasing and oscillating, the collective increasing at an escalating rate and the helicopter pitching nose down and rolling right – the commander asked, "You all right?" and the copilot answered, "No, I'm not happy, mate."

As the combined engine torques exceeded 100 percent, the commander asked, "We going round?" and the copilot replied, "Yeah, take... help us out."

The report said, "This request was not initially understood by the commander, and the copilot reiterated his request, saying, 'Help us out'. The commander took control approximately four seconds after the initial request for help and said, "I've got it, I've got it, I have got it, I have control, I have control" At the time, the helicopter's right bank angle increased to 38 degrees, its nose was about 38 degrees down, indicated airspeed (IAS) was 90 kt and increasing, and radio altitude was 290 ft, with a descent rate of 2,000 fpm.

A second after the commander took control, the report said, "a large left cyclic roll input was made, followed one second later by an aft cyclic pitch input". The helicopter's bank angle shifted to 7 degrees left, and pitch attitude shifted to 13 degrees nose-down; as the helicopter descended through 180 ft, IAS increased through 100 kt. Over the next six seconds, IAS continued to increase; vertical speed, which initially had been reduced to 1,320 fpm, increased to 1,690 fpm.

Aérospatiale SA 365N Dauphin 2

The Aérospatiale (now Eurocopter) SA 365N, first flown in 1979, is a twin-engine helicopter designed to carry two pilots and up to eight passengers. It is equipped with Turbomeca Arriel 1C gas turbine engines, each rated at 530 kW (710 shp).

Empty weight is 2,017 kg (4,447 lb) and maximum takeoff weight is 4,000 kg (8,818 lb). Maximum cruising speed at sea level is 140 kt, maximum rate of climb is 1,515 fpm, and service ceiling is 15,000 ft. Maximum range, with standard fuel at sea level, is 475 nm (880 km).

Source: Jane's All the World's Aircraft, UK Accidents Investigation Branch

'You All Right?'

"At 1832:45, the copilot uttered an expletive, as though disappointed, and the commander asked, 'You all right?'; the copilot said, 'Yep… no,' in a resigned manner," the report said. At 1832:47, the automatic voice alert device, which provided audio warnings of the helicopter's height above the surface, sounded a "100 feet" call.

The report described cockpit communications as "calm" and said that there were no indications of other problems. The helicopter was last recorded at 30 ft in a 12-degree nose-down attitude, a 20-degree right bank and an IAS of 126 kt. The recording ended at 1832:50.

Witnesses on the North Morecambe platform told investigators that the helicopter "appeared to be on a standard approach until it appeared to initiate a go-around, although it seemed faster and closer to the platform than normal," the report said. The helicopter then banked right and disappeared into darkness before the witnesses heard an impact with the water.

The fuselage broke apart on impact, and most sections of the helicopter sank. Rescue boats arrived 16 minutes after the crash from a multipurpose standby vessel that was near the platform. Bodies of six of those in the helicopter were recovered, but the seventh was not found.

The commander, who had flown helicopters in the Morecambe Bay gas field for 20 years, was the base chief pilot, a line training captain and a crew resource management instructor. He had an airline transport pilot license and an instrument rating, and had accumulated 8,856 flight hours, including 6,156 hours in type. Records showed he had completed 34 instrument approaches and 37 night deck landings in the 90 days before the crash.

The copilot had received helicopter flight training in the British Army and had flown emergency medical services helicopters for 2 1/2 years. He had been working for CHC Scotia for 13 months at the time of the accident and had 3,565 flight hours, including 377 hours in type. He had 467 hours of night flight—three of which were recorded in the three months prior to the accident. He had completed nine instrument approaches and seven night deck landings in the 90 days before the crash.

The helicopter was manufactured by Aérospatiale (now Eurocopter) in 1985 and had accumulated 20,469 airframe hours and 13,038 cycles. Records showed that it had been maintained in accordance with an approved maintenance schedule and was in compliance with all applicable airworthiness directives. Maintenance records for the 12 months preceding the accident showed no defects had been reported that related to the crash. A routine 50-hour maintenance check had been performed the day of the accident, and no problems were reported.

'A Particularly Dark Night'

Weather at the time of the accident included visibility of 3 to 7 km (2 to 4 mi) in mist and light rain or drizzle, scattered to broken clouds with a base at 700 ft, broken to overcast clouds with a base at 1,200 to 1,500 ft and surface wind from 130 degrees at 15 kt. A weather observer on a platform near the accident site said that conditions about 90 minutes before the accident included 4,000 m (2.5 mi) visibility in rain and skies obscured; an accurate assessment of the cloud base was not possible because the observer did not have appropriate equipment to measure it.

The report said that, although there was a half moon, the clouds completely obscured any light from the moon, and "it was a particularly dark night."

Data from the helicopter's integrated health and usage monitoring system (IHUMS), which incorporated the CVFDR, showed that no system fault warnings were activated during the accident flight. Two main gearbox exceedances were recorded—the first, when the combined engine torque exceeded 100 percent at an airspeed below 75 kt, and the second, after the commander took the flight controls, when the torque exceeded 94 percent with the airspeed above 75 kt.

Data also showed that, during the accident segment of the flight, the autopilot heading hold, IAS hold, altitude hold and area navigation (RNAV) modes were not used.

Two Distinct Phases

The report said that, because there was no evidence of any technical problem, investigators focused on human factors issues "to understand why two experienced pilots were unable to stop a serviceable helicopter [from] flying into the sea."

Investigators identified "two distinct phases" of the final approach. The first involved a "steady reduction in collective demand and a steady, positive change in pitch attitude," the report said. The second — which began after the commander's callout of "fifty-five," a reference to airspeed — involved a steady increase in collective demand as the helicopter began to climb, suggesting "a change in the appreciation of the helicopter's position or motion relative to the deck," the report said.

"The approach was flown essentially by reference to visual cues. In dark, overcast conditions, it is likely that some cues were degraded or absent. For example, without a distinct horizon, the assessment of pitch attitude and approach angle (by reference to the depression of the deck below the horizon) would be compromised."

The report noted that if recommended changes in helideck lighting had been implemented, better visual cues might have been available, perhaps enabling the crew to determine earlier in their approach that they had deviated from a safe approach path. The recommendations—to be mandated by the International Civil Aviation Organization beginning in 2009—call for installing green lights instead of yellow lights on helideck perimeters as a means of enhancing pilot situational awareness. Further trials by the U.K. Civil Aviation Authority (CAA) have led to the development of other helideck lighting patterns now being tested on offshore platforms[1].

The report said that judging the approach angle apparently had presented the crew with a significant challenge that might have been met by minimizing the number of variables involved— "by commencing the descent at a specified height and range, and maintaining a stable pitch attitude and a fixed relationship to the intended landing area"—or by using instrument references in addition to the limited visual cues. However, the radio altimeter was not in a location that enabled it to be conveniently included in the copilot's instrument scan, the report said, and the cockpit voice recorder indicated that the crew was not "using range information to determine the initiation of the descent or cross-checking with height, and except for the "fifty-five" call and one height call at 400 ft, the commander did not provide any information that may have assisted the copilot."

"The nature of the copilot's difficulty is open to conjecture; he may have commenced the descent too early or initially too steeply; or he may have used an inappropriate control strategy or inadvertently changed the pitch attitude. The underlying causes, however, most likely stem from the limited visual cues available and the paucity of instrument checks. Inadequate monitoring of the approach by the commander must also be regarded as a contributory factor."

The report also said that the commander appeared "ill-prepared" to take control of the helicopter and that both the go-around decision and the subsequent transfer of control to the commander appeared to have been handled inappropriately.

"It is possible that more positive crew interaction and a more active participation in approach profile monitoring by the non-handling pilot may have resulted in a positive outcome," the report said.

Monitoring the Approach

The report included a safety recommendation that CHC Scotia review its standard operating procedures (SOPs) for helideck approaches "to ensure that the non-handling pilot actively monitors the approach and announces range to touchdown and height information to assist the flying pilot with his execution of the approach profile."

The recommendation said that the non-handling pilot's assistance is especially important when an SA 365N copilot is flying an approach in poor visual conditions "and cannot easily monitor a poorly positioned radio altimeter".

A second recommendation to the operator called for a review of all SOPs concerning helideck approaches flown by all of its types "with the aim of ensuring safe operations."

Another recommendation called on the European Aviation Safety Agency (EASA) to ensure the prompt completion of research into instrument landing systems that would aid helicopter crews in monitoring approaches in poor visual conditions to oil and gas platforms.

A second recommendation to the EASA said the agency should investigate methods of increasing the conspicuity of immersion suits worn by flight crewmembers. Rescuers had told accident investigators that the yellow immersion suits worn by passengers of the accident helicopter were easier to see than the blue suits worn by the pilots.

The AAIB also recommended that the CAA ensure that recurrent training and checking of JAR-OPS (Joint Aviation Requirements-Operations), Part 3 approved operators be conducted in an approved synthetic training device.

A second recommendation to the CAA called on the agency to ensure that personnel who conduct weather observations from offshore facilities are "suitably trained, qualified and provided with equipment that can accurately measure the cloud base and visibility." The report noted that the employee who compiled weather data on the evening of the accident had not received formal training and had no equipment to aid in his observations.

After the accident, the operator provided more specific procedures and guidance for actions to be taken in the event of pilot disorientation or incapacitation; developed go-around procedures that included use of the autopilot coupler; developed and published a night circuit pattern; and continued development of its policy to train all pilots in synthetic training devices.

This article is based on AAIB Accident Report No. 7/2008: Report on the Accident to Aérospatiale SA 365N, Registration G-BLUN, Near the North Morecambe Gas Platform, Morecambe Bay, on 27 December 2006.

Note

1. CAA. Enhancing Oshore Helideck Lighting, CAA Paper 2004/01.

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Separation Anxiety

Imminent approval of software upgrade promises safer TCAS II collision avoidance system logic

by Wayne Rosenkrans

Traffic alert and collision avoidance system (TCAS II) Version 7.1 – a software upgrade developed by European and U.S. specialists – is expected to clear one of the last technical hurdles on its five-year path to operational readiness during April. Possibly by mid-2010, the upgrade installed in new TCAS II equipment will fix two serious problems in today's collision avoidance system logic and make other minor improvements. Strategic decisions on whether civil aviation authorities will recommend or require retrofitting Version 7.1 logic are pending.

One problem is that Version 7.0 logic does not reverse some resolution advisories (RAs) when a reversal is required to resolve the threat of collision between two equipped aircraft while both are climbing or descending within a vertical distance of 100 ft of each other. The other problem is flight crews with vertical speed TCAS II displays manuvering in the wrong vertical direction after receiving one of four "Adjust Vertical Speed, Adjust" (AVSA) RAs. AVSA RAs, now considered ambiguous by many safety specialists, advise a pilot to reduce the aircraft rate of climb or descent to 0, 500, 1,000 or 2,000 fpm for collision avoidance, and they lack any upward or downward aural annunciation.

AVSA RAs have accounted for nearly two-thirds of all RAs in European airspace, occurring mainly in geometries involving level-off at 1,000-ft altitude increments as assigned by air traffic control (ATC). Pilot training solutions – for example, re-emphasizing that the proper response to any AVSA RA is a reduction in vertical speed while maneuvering toward level flight – alone have not worked, European specialists say.[1]

Version 7.1 solves the first problem with a significant software code change hat monitors compliance with RAs and enhances the reversal logic, allowing reversals when the aircraft are vertically within 100 ft. Version 7.1 solves the second problem by replacing AVSA RAs with a "Level Off Level Off!" RA. Independent validations by computer simulations with actual air traffic data from several European sources, Boston and New York have demonstrated safe and effective software performance.[2]

A Eurocontrol recommendation in July 2008 urged the industry to aggressively pursue this software upgrade when revised U.S. and European technical standard orders (TSOs) for TCAS II take effect. "As TCAS II Version 7.1 provides further significant reduction in the risk of midair collisions, it is therefore strongly recommended that TCAS II Version 7.1 is implemented as rapidly as possible," Eurocontrol said.[3]

The organization's policy position is that until all current TCAS II-equipped aircraft and new aircraft are Version 7.1 compliant, there will be no short term reduction in the unacceptable risk of midair collision to the Version 7.0-compliant aircraft in Europe, a risk equivalent to one midair collision every three years. Forward fit plus retrofit delayed not more than two years would reduce this risk by a factor of four (ASW, 10/08, p.53), Eurocontrol said.[4] Some European specialists say that no hardware modifications should be necessary, and they have proposed that International Civil Aviation Organization (ICAO) standards require TCAS II Version 7.1 equipage by Nov. 30, 2010, for new aircraft and by March 31, 2013, for existing aircraft.[5]

In December 2008, John Marksteiner, the U.S. Federal Aviation Administration (FAA) representative to an ICAO aeronautical surveillance working group, said that it would be premature for ICAO to consider a timeline for mandatory worldwide carriage of TCAS II Version 7.1 without further study.[6] He cited several issues as still unresolved, including different risk levels in the United States and Europe, possibly time needed for manufactures to develop new equipment and retrofit packages, and an unknown scope of hardware upgrades.

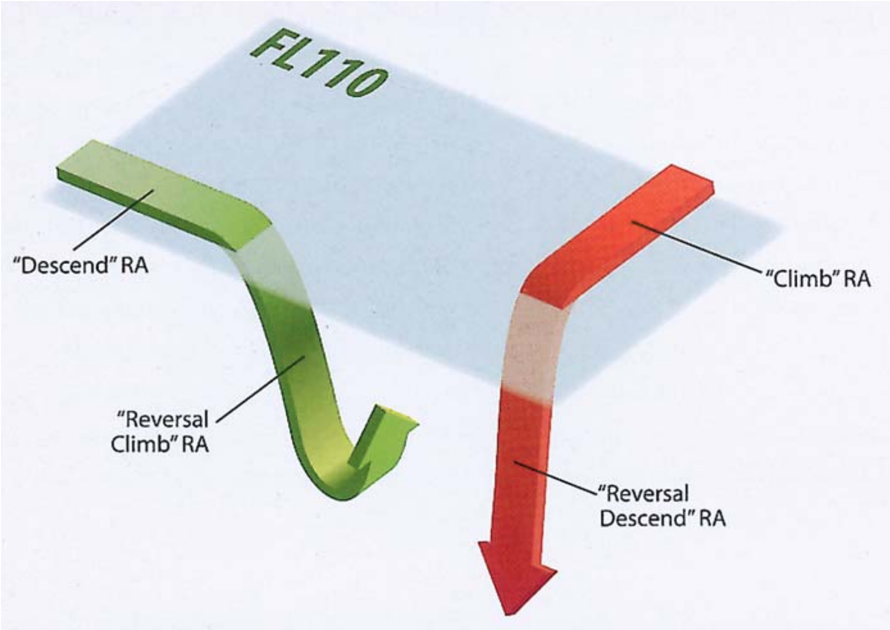
He raised other questions to consider. Will standard cost-benefit analyses show that requiring Version 7.1 retrofit is justifiable instead of clarifying the meaning of AVSA RAs and improving pilot compliance with Version 7.0 RAs through training? How effectively could midair collision risk be mitigated without Version 7.1 compliance by training pilots to climb and descend at less than 1,500 fpm in the last 1,000 ft before level-off at the assigned altitude/flight level? Would analysis of RAs, based on pilot reports and monitoring of downlinked Mode S RA data, enable civil aviation authorities to identify "RA hot spots" in their airspace and mitigate the Version 7.0 shortcomings – with procedural changes, for example?

After TSO revisions for the Versions 6.04a-to-Version 7.0 logic upgrade were issued in 1999, the European Joint Aviation Authorities in January 2000 mandated TCAS II Version 7.0 carriage by all civil turbine-engine aircraft with more than 30 passenger seats or maximum takeoff mass of more than 15,000 kg (33,070 lb). U.S. Federal Aviation Regulations (FARs) for these aircraft currently require Version 7.0 or equivalent logic but allow version 6.04A Enhanced if that logic was installed before May 1, 2003, and can be repaired to conform to its original minimum operational performance standards.[7]

U.S. and European TSO revisions expected during 2009 will establish the dates when newly identified or manufactured TCAS II equipment must be Version 7.1 compliant. Steve Plummer, designated federal official representing the FAA at the March 12 meeting of RTCA Special Committee 147 (SC-147), offered no details but said that the FAA is now evaluating what the appropriate strategy should be for implementing Version 7.1, working on harmonizing rule-making strategy with the European Aviation Safety Agency (EASA) and, like others, proposing Version 7.1-related language for ICAO standards and recommended practices. The RTCA meeting included representatives of its counterpart on TCAS II standards, the European Organisation for Civil Aviation Equipment (EUROCAE) Working Group 75 (WG-75).

Last-Minute Modification

The TCAS II Version 7.1 revision to minimum operational performance standards was published by RTCA as RTCA/DO- 185B in June 2008 and by EUROCAE as Document ED- 143 in September 2008. A post-revision validation process led to a delay in completing the TSOs, however, when a minor discrepancy came to light between the pseudocode[8] and state charts.[9] In one multi-aircraft scenario—that is, involving more than two aircraft—run on a standard computer simulation program, the RAs did not agree. This led to more development, testing, multi-site verification and validation of modifications issued as Change 1 to this standard.



TCAS II Version 7.1 Solution to Pilot Error
TCAS = traffic alert and collision avoidance system; RA = resolution advisory; FL = flight level

Note: Current TCAS II logic allows only one climb/descend sense reversal, and reversing an ongoing RA is not permitted while the aircraft are maneuvering within a vertical distance of 100ft of each other. The illustrated enhancement in the new Version 7.1 logic is that if the aircraft with the red flight path decends contrary to a "Climb" RA, immediate reversal RAs will be generated for pilots of both aircraft.

Source: Eurocontrol Safety Issue Rectification Extension Plus Project

Change 1 eliminates the corrective green arc in TCAS II display symbology for a weakening RA for the aircraft in the middle of a multi-aircraft encounter, according to an SC- 147 working group report presented by Andrew Zeitlin of The MITRE Corp. Center for Advanced Aviation Systems. Validations by Eurocontrol and Massachusetts Institute of Technology (MIT) Lincoln Laboratory confirmed that the modifications were safe and effective, Zeitlin said.

On April 21, SC-147 is scheduled to approve Change 1 to RTCA/DO-185B. Probably later in the second quarter, the RTCA Program Management Committee is expected to approve this change, in turn enabling the FAA to issue TSO C119c, "Traffic Alert and Collision Avoidance System (TCAS II) Airborne Equipment, TCAS II With Optional Hybrid Surveillance." Parallel work in Europe included EASA's March 12 issuance of Notice of Proposed Amendment No. 2009-03 similarly updating European Technical Standard Order ETSO-C119b.

FAA Monitors RAs

The FAA has been deploying monitoring systems at 20 U.S. sites that collect data on TCAS RAs for analysis of both safety and air traffic management. As of March, the systems were operational in Boston, Los Angeles, New York and Philadelphia, said Neal Suchy, the FAA's TCAS program manager during Version 7.1 development.

This FAA analysis first has focused on business jets operating below Class B airspace and RAs occurring during multi-aircraft encounters, he said. Three more California sites—Ontario, Long Beach and Oakland—are scheduled to be deployed by the end of May, and the FAA also expects to monitor TCAS II performance near Louisville, Kentucky, using automatic dependent surveillance-broadcast technology in the nation's first Next Generation Air Transportation System (NextGen) environment.

During development of Version 7.1, Eurocontrol contractors used TCAS II computer simulations to validate the performance of the AVSA RA-related enhancements. They first were compared with version 7.0 using aircraft encounter data from Europe. The effort comprised safety aspects, human factors aspects and operational aspects.

After reviewing the European results, however, RTCA SC-147 specialists wanted to confirm that AVSA related enhancements would not disrupt FAA terminal control area operations or induce a conflict with a third-party aircraft flying near a TCAS II-equipped aircraft, given the country's dense mixes of air carrier and general aviation traffic operating under different flight rules. In response, a Eurocontrol analysis identified 92 initial AVSA RAs among a total 992 RA encounters from Boston-area data recorded by MIT Lincoln Laboratory, with 81 AVSA RAs suitable for detailed study.

These RAs occurred during six months of 2006 within a 60-nm (111km) radius of Boston Logan International Airport, and the Eurocontrol contractors received both FAA radar data and RAs downlinked by MIT from a Mode S transponder sensor. About half of the recorded AVSA RAs involved two aircraft; the remainder involved three to seven aircraft in the surrounding traffic.

This analysis found that the AVSA related changes in TCAS II Version 7.1, assuming that all aircraft in the airspace were equipped alike, would generate one "Level-off, Level-off" RA about once every three days in the Boston airspace compared with an average of 18 RAs of all types recorded every three days. The new "Level-off, Level-off" RA did not induce a conflict with any third-party traffic, and the likelihood of such a conflict was deemed "extremely remote."

Eurocontrol contractors next looked at three months of 2007 FAA radar data from recorded aircraft encounters that occurred within a 60-nm radius of John F. Kennedy International Airport. They did not have downlinked Mode S transponder data available from this airspace, so RA data were extrapolated based on an assumption that the aircraft were fitted with TCAS II operating in RA mode as required by current FARs.

Pilot-Friendly Benefits

Eurocontrol, its research contractors, other European aviation organizations and the FAA expect introduction of the "Level-off, Level-off" RAs in TCAS II Version 7.1 to be welcomed world-wide. The Version 7.0 logic had been designed with an expectation that pilots of converging aircraft would become comfortable ensuring initial separation solely by simultaneously modifying their present climb/descent rates rather than climbing, descending or leveling off. In such scenarios, however, todays TCAS II may direct one flight crew to reduce climb rate from, say, 2,500 fpm to 1,000 fpm in about three seconds, Eurocontrol noted. Unlike that scenario, intuitively simple "Level-off, Level-off" RAs will be of shorter duration and typically involve less altitude change.[10]

"In the same geometries, the Version 7.0 logic can post increasingly stronger AVSA RAs, possibly up to a positive RA, in quick succession if the vertical convergence rate is not decreasing as fast as expected, which constitutes a complex RA sequence."said the Eurocontrol report on New York airspace simulations. "With [Version 7.1 logic], this complex sequence can be replaced by a single Level-off RA, as it is more efficient in rapidly reducing the vertical convergence."

For ATC, one of the main safety benefits of Version 7.1 will be that pilots receiving RAs will not continue in the same vertical direction, Eurocontrol said. A conclusion from its analysis of Boston data was that "TCAS II Version 7.0 issued RAs that left both aircraft evolving in the same vertical direction and, despite appropriate pilot responses, the target vertical separation of 350 ft was not achieved at their closest approach."

Notes

1. Arino, Thierry; Chabert, Stephan; Drevillon, Herve. "Decision Criteria for Regulatory Measures on TCAS II Version 7.1." Eurocontrol Mode S Programme, DSNA and Egis Avia Safety Issue Rectification Extension Plus (SIRE+) Project. July 17, 2008.

2. Arino; Drevillon. "Operational Performance of CP115 in New York Airspace" Dec. 4, 2007.

3. Arino; Chabert; Drevillon.

4. Eurocontrol. "TCAS II Version 7.1" <www.eurocontrol.int/msa/public/standard_page_ACAS_Upcoming_Changes.html>.

5. Loscos, Jean-Marc; Mallwitz, Roland; Potier, Eric; Woods, Ray. "Update to ACAS Mandatory Carriage." An ICAO working paper presented in Montreal to the Aeronautical Surveillance Panel Working Group of the Whole. Document ASP-WGW/1-WP/12. Nov. 24, 2008.

6. Marksteiner, John. "ACAS Carriage Considerations." An ICAO working paper presented in Montreal to the Aeronautical Surveillance Panel Working Group of the Whole. Document ASP-WGW/I-WP/17. Dec. 5, 2008.

7. Eurocontrol ACAS [Airborne Collision Avoidance System] Programme; Sofreavia; CENA. "European Maintenance of TCAS II Version 7.0: Project EMOTION-7 Final Report." Report no. ACAS/03-003. January 2003.

8. *Pseudocode* is an informal structured language that programmers use to convey to other people high-level descriptions of computer programming algorithms.

9. *State Charts* in RTCA/DO-185B are tables showing a transition, code location, trigger event, true/false status of conditions and output action in the collision avoidance system logic.

10. Arino; Drevillon. "Operational Performance of CP115 in Boston Airspace." March 9, 2007.

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At Last: The answer to the Meaning of Life, The Universe and Everything...

by Major C P Evans, MoD DARS SO2 Engineering Rotary Wing - Directorate of Aviation Regulation and Safety

The answer is, as some of you may already know, '42' however, that isn't terribly helpful. As it happens it wasn't terribly helpful to Arthur Dent either. Despite everybody knowing the answer, the types and numbers of incidents caused by maintenance error are not decreasing. As a result these continue to cause a reduction in operational capability and incur costs, both in terms of components and rectification man-hours.

Maintenance Error and Regulation - an Evolution

The DARS engineering team has been looking at the data available covering maintenance error (The term 'maintenance error' has been used generically to refer to all types of aircraft-related error which occur while, or originate when, the aircraft is not being operated by qualifi ed aircrew, and includes maintenance/servicing error and ground handling error. It also includes errors made or originating on uninstalled aircraft components). We have attended meetings of the UK Flight Safety Committee, the Flight Safety Working Group and the Human Factors Group (Engineering) of the RAeS. Additionally we have looked at a number of data sources: CHIRP MEMS - CAA Mandatory Occurrence Reports - US Federal Aviation Administration (FAA) Service Diffi culty Reports - Australian Transport Safety Board (ATSB) Air Safety Reports and our own PANDORA database. It has become clear that the two major causes of both civilian and military maintenance error are:

1. Incorrect installation of components; often due to poor marking or ease of wrong assembly.
2. Failure to follow laid-down procedures; often due to either incomprehensible or inaccurate publications, or the unavailability of the correct publications.

The data sets that are available identify these same issues but store and manipulate data in different ways. If progress is to be made on reducing and keeping down maintenance error a better way of collecting and using this data is essential. After an evaluation competition the contract for an all new Aviation Safety Information Management System (ASIMS) has been let. This will supersede all the current Signals based occurrence reporting systems. The requirement also includes the need for collection, correlation and use of engineering/maintenance occurrence reports. These will utilize the Maintenance Error Decision Aid (MEDA) and support a Maintenance Error Management System (MEMS) as well as being compatible with future Error Management Systems.

Historically though, the immediate reaction to an incident or accident has been increased regulation or procedures. However, there has been little or no corresponding reduction in maintenance errors. This pres criptive approach is now seen by the DARS Engineering Branch as counter-productive. There seems to be a corporate belief that ever-increasing procedures and correspondingly lengthy publications improve safety. This is giving a false sense of security. An example to demonstrate the fallacy of over-regulation is the Dutch town of Drachten. In a road traffi c experiment they have removed the town's traffi c lights, cycle lanes, pavement barriers, white lining etc. The accident rate has tumbled and congestion has been eased. Drivers, cyclists and pedestrians are no longer blindly following the regulations and have to think for themselves. Closer to home, railings have been removed from some pavements along Kensington High Street. This has dramatically reduced pedestrian casualties. These outcomes are not surprising. Drivers and pedestrians were concentrating on signs and barriers to keep them safe; with their removal, they have to focus on what other road users are doing.

Looks like we put the gearbox in back to front

There is a read across to MOD aviation. With so many rules and procedures, no person can hope to be current on them all, so they tend to scan the sections that appear important. When they do need the laid-down procedures, they are often not available at the work place, difficult to use, or inaccurate. Likewise they can never be reviewed often enough to keep them current. The required turnaround for MOD F765 publication amendment is 3 months (iaw JAP 100A 01). This process can, in some cases, actually take up to 3 years, with little or no feedback being given to the originator.

Allocation of Resources

The enduring dilemma, or mismatch, of engineering resources is illustrated below. This is particularly relevant to the Support Helicopter (SH) and Air Transport (AT) fleets due to increased operational tasking:

Number of Aircraft Engineers x Productive Working year = X Engineering Hrs

X Engineering hrs / Maint Man Hrs per Flying Hr (MMH/FH) = Y Airframe Hrs

However,

Number of Pilots x Currency or Tasking requirement = Z Flying Hrs

Z is always much bigger that Y - i.e. Systemic Engineering undermanning.

As an example, the Apache was procured on an estimated 8-12 MMH/FH basis and REME Workshops were established against this fi gure. The recently rebalanced Forward/Depth REME Workshop establishments were predicated on 17.8MMH/FH. By April 2008 the actual figure had risen to very nearly 30MMH/FH. While this figure has prompted some action and mitigation, the establishments remain extant and the systemic undermanning stands.

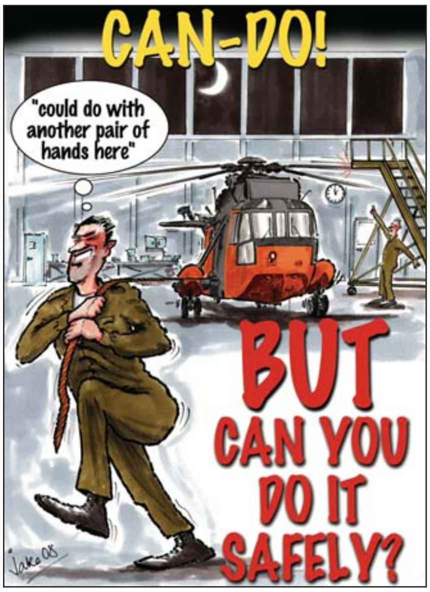
Service personnel generally work in an environment of conflicting demands between maintaining their skills as a tradesman and skills as a serviceman; which often takes secondary importance. Working routines that properly accommodate training for Ops, for aircraft engineers, often conflict with the ongoing requirement to provide serviceable aircraft. When a Sqn is training for Ops, the engineers are under considerable pressure, which continues on Ops and even into recovery. The level of pressure, both actual and perceived, is often different depending on the hierarchical position of the individual concerned. Whilst some pressure is often needed to achieve good levels of arousal, perceived pressure regularly results in a misplaced 'Can Do' attitude. Breaking this cycle is vital; remembering that under-arousal can be just as insidious in maintenance errors.

Perceived pressure is an often-quoted contributory factor in ground handling incidents, when Service personnel violate laid-down procedures to 'get the job done.' Ground handling incidents are a major issue in the AT fl eets where many types of GSE attend the aircraft during turnarounds. During the period Jul 05 to Oct 07 there were 75 ground handling incidents at a particular AT unit. That is 3 incidents a month, indicating that perceived pressure, non-adherence to procedures and a 'can do' attitude are very real issues.

Error Provocation

An important error-provoking factor, as a result of systemic or even perceived undermanning and reduced experience levels, is the creation of routines and norms – however unsafe – that support Ops. One of the differences between Ops and normal peacetime workload can be distraction, given that in the 24/7 world of Ops all are heavily focused on the operation in hand. A stream of domestic, administrative, trivial and other distractions punctuate the normal peacetime working day. However, lack of in-theatre parts can be as concerning and lead to maintenance errors, often from shortcuts, in an attempt to achieve the tasking.

The Effects of Operations on Rotary Wing Flight Safety[1], while concentrating to a large extent on the Aircrew issues, is highly



pertinent to maintainers' error-provoking factors and, especially in light of recent accidents, applies equally to fixed wing and multi-engine aircraft.

European Helicopter Safety Analysis Team (EHSAT)

DARS has been conducting a review of military helicopter accident Board of Inquiry (BoI) Reports, against the EHSAT methodology. This attempts detailed classification of the organizational and supervisory factors, as well as any unsafe acts or preconditions, of an accident; using the Human Factors Analysis and Classifi cation System (HFACS).

The BoI Reports show, in addition to the actual cause of the accident, that there are always many more contributory factors and observations. These, in an open reporting culture, should have become Incident or Occurrence Signals and/or DCORS Reports; however these 'near misses' often only seem to surface during a BoI. The indication is that we are not operating in the open or reporting culture that we need.

I've checked that the checker checked has been checked so can you check it now?

Maintenance Error Management System (MEMS)

Since Jan 03, JAR 145 (subsequently EASA Part 145) civilian organisations have been required to '…establish an internal occurrence reporting system…' The CAA's Mandatory Occurrence Reporting (MOR) and Confidential Human Factors Incident Reporting Programme (CHIRP) both have military equivalents, and yet civilian regulation goes further, mandating the adoption of a MEMS. Since Mar 07 the CAA has sought, through Airworthiness Notice No 71, '…to provide an environment in which errors may be openly investigated in order that the contributing factors and root causes of maintenance errors can be addressed using a system that would complement, not supplant, their current reporting systems.' In short, a MEMS is now a mandatory requirement within civil aviation.

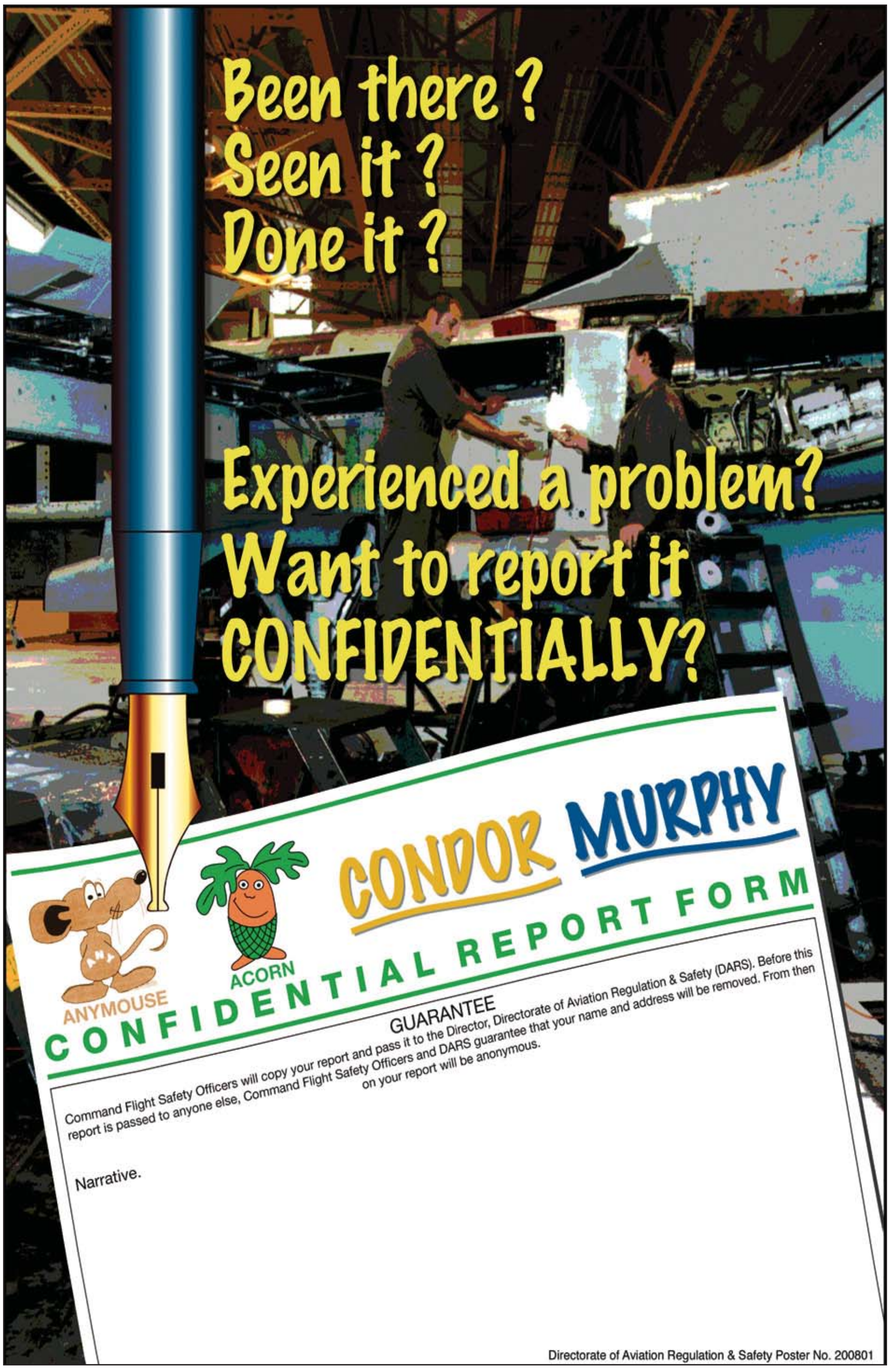
Apache Helicopter Depth Support Unit (AHDSU) – Introduction of a MEMS

As a result of a major 'near miss' incident the AHDSU introduced a Maintenance Error Management System (MEMS) in Nov 07. This has drawn together Self Assessment, HF training and the Maintenance Error Decision Aid (MEDA). Baines Simmons Ltd was the chosen provider. It should be noted however that CAA Self Assessment tools and MoD sponsored HF training are available. Additionally MEDA is an open source (MS based) investigation tool originally developed by Boeing, although investigatory techniques training is required to use this.

While many would hope for an Open and Just Culture, the MoD does not always have a Reporting Culture, despite the availability of many open and confi dential systems. While DARS training and instruction refers to a 'misplaced' can-do attitude, there seems to be an almost institutionalized can-do attitude – which frequently leads to no-one reporting when a situation becomes unsafe. There have been very few DCORS (formerly Murphys, CONDORS, Anymouse or Acorns) submitted to the DARS, from across Defence, this year; none of which have been raised by an engineer. In sharp contrast the AHDSU has received over 180 FURBYs (In-house reporting scheme) since Nov 07.

Having delivered HF training to everybody in the AHDSU, the Depth Support Manager brought in a MEMS and his Policy Statement introduced a just culture for the management of maintenance error. This explicitly requires a willingness to report hazards and a process for dealing fairly with personnel, both civilian and military. The AHDSU Culpability Chart deals, diagrammatically, with everything from sabotage and malevolent damage – through progressively diminishing culpability – to system-induced and blameless errors.

With only 200 mixed civilian and military personnel, the AHDSU reporting rate is excellent. The formal MEDA investigations carried out so far have produced some clear efficiency and safety results, including: highlighting the wasted effort in cannibalizing AH doors (as a result of the way they are



manufactured and fitted); and the easily-made error, and subsequent impact, of fitting an APU air valve 180? out-of-alignment, as well as discovering that subsequent follow-ups are impossible. It is now hoped that this initiative will be rolled out across the AH force and beyond.

ASG Study

The RAF ASG have carried out a review of recent maintenance-related RAF F765B Flight Safety Investigation Reports. This review highlighted that significant improvements could be made to the investigation process to enable a better understanding of the error provoking conditions surrounding flight safety incidents, especially at the organizational level. Additionally, where error-provoking conditions had been identified, in around 50% of cases these had not been addressed. This has highlighted the need for a fully integrated Error Management System within the RAF maintenance organization. The RAF are now developing an Error Management System (EMS), utilizing the services of Baines Simmons Ltd. The ASG are working closely with DARS to ensure that any solution offered is cognizant of the future intentions for MoD-wide policy.

The RAF's HF (M)EMS programme is to be rolled out simultaneously across most aircraft fleets at 12 MOBs[2]. This ambitious implementation strategy will be reviewed after the results of the diagnostic phase[3] are known. DARS staff will continue to monitor the implementation and support the RAF project where necessary.

Conclusion

Aircraft engineers, across military aviation, are overburdened with regulation. Where there are resource, or other error-provoking conditions, maintenance errors become inevitable. The burden of regulation needs to be addressed. The introduction of ASIMS and MEMS to the current procedures and some form of MEDA could and should improve matters. However; there is a long way to go and there are NO quick fixes.

1 DARS 3/1/5 dated 3 Apr 07.

2 Marham, Lossiemouth, Leuchars, Coningsby, Cottesmore/Wittering, Odiham, Benson, Waddington, Kinloss, Brize Norton, Lyneham and possibly Northolt.

3 The diagnostic phase commenced in Sep 08 and assesses the existing organizational and individual attitudes to maintenance error.

This article originally featured in the DARS Aviate Journal. Winter 2008/9

Using Weather Radar to Counter FL Cells

by Erik Eliel

It's what you can't see that can hurt you.

Near LBL, [the crew] saw a patch of blue sky to the right front and painted nothing [on radar] in front of them. The encounter occurred when a large buildup appeared in front of the airplane with less than two seconds notice. The NTSB report goes on to say "the airplane experienced airspeed excursions from about 275 knots to 225 knots with an altitude loss of 500 feet. During the encounter, the airplane also experienced small hail. Other aircraft in the area reported no conditions greater than light turbulence."

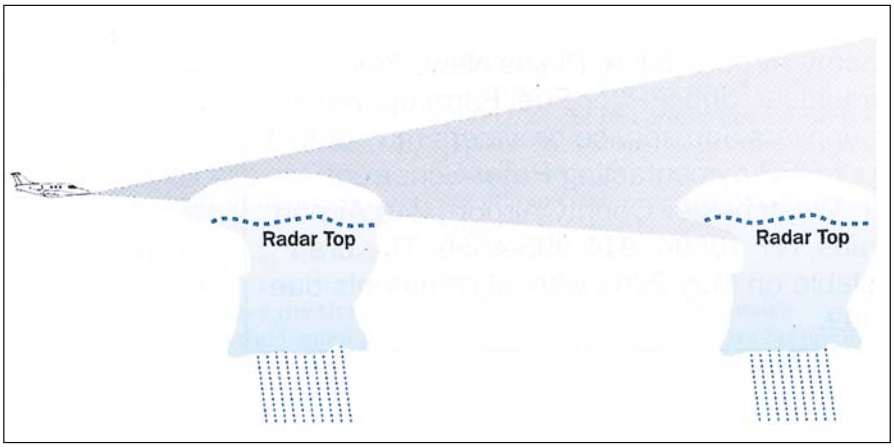
Every now and then, a professional flight crew inadvertently penetrates the top of a thunderstorm during cruise flight; in the forgoing incident, the pilots were cruising at FL 370. With a little bit of knowledge, however, this is almost always avoidable.

To understand how these events can happen, a basic review of thunderstorm anatomy and weather radar capability is necessary.

As FAA Advisory Circular 00-24B warns, "A thunderstorm packs just about every weather hazard known to aviation into one vicious bundle," including moisture in just about every state of existence you can imagine. Although there are no absolutes when it comes to thunderstorm anatomy, it simplifies this discussion to separate the vertical structure of a typical U.S. thunderstorm into two sections.

The lower and mid parts of such storms tend to be composed of "wet" droplets of adequate size to react sufficiently with radar energy, so lumping those two sections together they become the reflective portion of a cell. To a pilot, this part of a cell will be seen on the display as some combination of green, yellow, red and, for most business aircraft radar displays, magenta. There is an imaginary horizontal line at the top of this area that is referred to as the "radar top," because it is the upper vertical boundary of detectable moisture by aircraft weather radar.

The topmost section—above the radar top—then, is different. Here, moisture also exists, but commonly in a dry, frozen state that interacts poorly with aircraft radar energy. Do not confuse the radar top with the actual top, since the latter normally will be several thousand feet higher. The significance of this is that the same hazards—turbulence, hail, lightning, etc.—exist in the upper part as in the lower reflective part, but encounters typically catch pilots off guard because the radar is capable of providing little or no warning.



Traditional tilt settings that eliminate ground returns on longer display ranges are classic setup for an inadvertent penetration while cruising in the upper flight levels. Here, the distant cell would be displayed since the bottom of the beam is below the radar top. However, the closer cell is being over-scanned and would not be detected by the radar. By lowering the tilt, both cells would be displayed and easily avoided.

In order to successfully avoid thunderstorms, you have to see them. If flying in IMC or at night, observing them out the windscreen may not be possible, leaving radar as the predominant tool. Unfortunately, the upper dry, frozen part of a thunderstorm typically coincides with the cruise altitudes of high-performance jet aircraft. Whether or not a cell will be seen is a function of tilt management. Specifically, the antenna tilt must be set so that radar energy is "aimed" at, or interacts with, the detectable moisture in the reflective part of the cell.

Frustrating Physics

The ability of a radar system to focus the energy is governed by physics, specifically the size of the antenna. Small antennas, like those on aircraft, complicate the situation because they broadcast a wider, more diffuse beam — an undesirable characteristic, but a limitation pilots are stuck with. Larger antennas focus the energy better, which is desirable.

Almost every pilot who has flown radarequipped aircraft has probably heard about the common tilt technique, handed down through the generations: Lower the tilt until ground returns are displayed, and then raise it just enough so they mostly disappear. For an aircraft cruising in the upper flight levels, this is a classic setup for penetrating the top of a thunderstorm. To explain how this happens, let's use specific numbers.

Relatively speaking, all aircraft antennas are small, but the smallest of the antennas further exacerbate the situation. A common size for radars in today's business aircraft is 12 inches, which yields approximately an eight-degree beam. At 100 miles this translates to a beam diameter of about 80,000 feet. If the antenna is properly aligned, using zero degrees tilt puts the center of the beam approximately co-altitude (disregarding curvature of the earth) leaving about 40,000 feet worth of beam above, and an equal amount below, the aircraft.

An aircraft cruising at FL 400 with a 100-mile range selected would typically observe a few ground returns at the perimeter of the display. Thunderstorms at 100 miles would be easily detected, as radar energy would be interacting with the reflective part in the lower to mid altitudes. The associated pattern of colors—green, yellow, red and possibly magenta—give the active sections an unmistakable signature. However, if the tilt remains at zero degrees, the intensity of the cell may appear to weaken as the aircraft approaches it. If that seems counterintuitive, think about the bottom of the beam. As the distance to the cell decreases, the bottom of the beam scans progressively higher and higher in the cell.

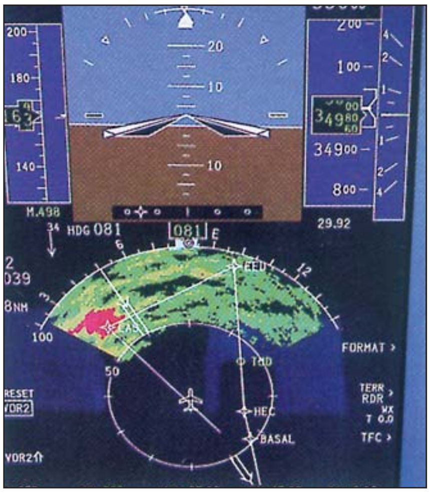
Twenty miles from the cell, the total width of the beam would be only about 16,000 feet, and with the tilt still set to zero degrees, the bottom of the beam would be 8,000 feet below the aircraft, or about FL 320, and at a distance of 10 miles would be approximately FL 360. There is a high risk that these altitudes will be at or above the radar top for many hazardous cells, meaning they might appear as either a weak green return or perhaps no return at all. Either way, it is deceptive and penetration of either the frozen top or the hazardous area just above the actual top is probable if it is in the aircraft's flight path.

As pilots, we've been taught to remain at least 20 miles away from storms identified as severe or that give an intense radar echo. An increased margin of safety is appropriate in some situations, so assuming the cell can be seen (visually or on radar) a turn to stay at least 20 miles away should always be the goal. But in day-to-day professional flying, classroom theory and real world dynamics occasionally clash, and a pilot cruising in the upper FLs, looking at a weak green return on the display may not recognize its significance. If it is part of a line of weather bracketed on either side by more intense cells, forging directly toward it might appear to be a reasonably safe plan. Do not fall into this trap.

Minimizing the Risk

The solution is proper tilt management. The tilt must be "aimed," or lowered sufficiently so the radar energy interacts with detectable moisture in the lower to mid sections of the cell as the distance to the cell decreases. However, with longer ranges selected, ground returns may flood the display, and if there are too many, that can be a real nuisance.

But the benefit of having a solid band of ground returns on the outer portion of the display is significant. Archie Trammell has taught this technique to countless numbers of pilots including me, and I have used it during thousands of flying hours. It guards against one of the biggest threats pilots face: failure to identify severe attenuation caused by precipitation. By having a solid band of ground returns displayed —no more than about one-third of the outer portion of the display—total attenuation can be readily identified when ground returns are absent from the area directly behind a storm. This is a classic radar shadow. Failure to identify them and the cells intense enough to cause them has been causal in numerous aircraft accidents over the past 30 years.



Typical ground returns given a cruising altitude of FL 350, a 12-inch antenna and zero degrees antenna tilt. Raising the tilt will reduce or eliminate the ground returns, but doing so significantly increases the risk of over -scanning close-in cells – the ones capable of causing damage and injury. Strong return at 10 o'clock and 70 miles is Las Vegas.

There are three absolutes when dealing with cells this intense. One, without exception, is that they are very hazardous. Two, the true shape and gradient of the cell may be grossly misrepresented on the display because radar energy is not completely penetrating the storm. (If there do happen to be any weak weather returns in the shadow, the intensity will be significantly understated.) Three, radar energy is unable to make the two-way trip through the offending cell, and so anything in the shadow area, where the most intense weather may reside, can remain cloaked.

Taken at FL 370, return at 2 o'clock and 20 miles appears weak because the bottom of the beam is approaching the radar top. Note the tilt is set to zero degrees, 80-mile range selected, with no ground returns displayed.

The solution to unwanted ground returns that are displayed is learning how to read them. Operating the radar with a band of ground returns on the outer portion of the display on clear weather days will provide a "mental blueprint" of what normal ground returns look like. Cities, mountains, the plains and bodies of water all have unique signatures. Just as a doctor knows what constitutes "normal" when interpreting an x-ray image, a pilot must know what constitutes "normal" the ground returns. Once this level of proficiency is achieved, deviations from the norm — like abnormalities on an x-ray — will be more readily identified.

So, even though cells might be embedded in ground returns, the signature/profile of intense weather is unique and difficult to miss. If there is any confusion about which returns are from the ground vs. those from a thunderstorm, be patient and alert. Thunderstorms will self-identify when they march out of the ground returns on the display.

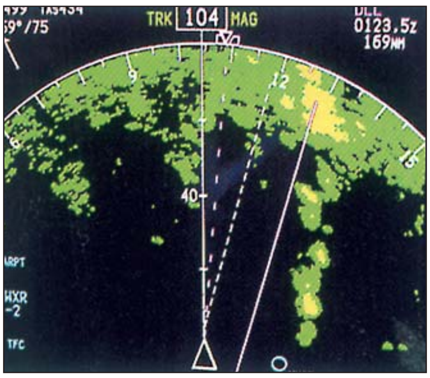
As already mentioned, a small antenna yields a wider beam. Setting the tilt to zero or minus one degree may begin to flood the display with ground returns as longer ranges are selected. The temptation will be to raise the tilt to eliminate them, but a risk management approach suggests doing otherwise. Some considerations follow.

Using a shorter selected range with sufficient down-tilt is a good option when weather is anywhere near the aircraft. Details—and details are good—are easier to see on shorter displayed ranges. Keeping a band of ground returns on the outer perimeter of the display will be more easily managed also. This reduces the risk of overscanning close-in targets. The downside: When converted to time, shorter ranges often don't provide sufficient warning of approaching weather. No one likes weather surprises, but exclusively selecting a shorter range will provide them.

View from the windscreen tells a different story. It was a very hazardous cell extending slightly above our cruising altitude and growing rapidly.

Exclusively using a longer range with a tilt setting that eliminates ground returns may give more notice of approaching weather if it is both tall and reflective, but generally speaking, it is a bad idea. Weather 150 miles away can't hurt you or your aircraft, so even though knowledge of its existence is important, it is the close-in weather—the stuff that can cause damage and injury—that takes priority. Using long ranges with the tilt set so that no ground returns are displayed is a setup for an inadvertent penetration.

Perhaps the most obvious technique then, is to periodically alternate the tilt and range. This may slightly increase pilot workload, but it is not nearly as workload intensive as diverting to the nearest field with aircraft damage and injured passengers. The default setting when weather is anywhere near the aircraft is a shorter range—say, 50 miles to 80 miles—and a tilt setting that puts ground returns on the outer one-third of the display, approximately. As hazardous weather intrudes inside this distance, reduce the range sufficiently to reveal adequate detail. But every now and then, select a longer range with a slightly elevated tilt for a few sweeps to see what else is out there. This should provide sufficient notice of approaching weather.



Lowering the tilt reveals the actual situation. The threat was not an isolated cell, but rather a line of hazardous weather masked by other clouds. Even though a band of ground returns is now visible at the outer perimeter of the display, embedded weather is still visible (patch of yellow returns at 1 o'clock and 60 to 80 miles). Note also how the cells self-identify when they march out of the ground returns.

If you are lucky enough to have a configuration that allows each pilot to independently control the radar tilt and gain for his or her respective display, then consider setting one side to longer range with a tilt setting that does not flood the display with ground returns, and the other side to a shorter range and a lower tilt setting as described previously. Provided weather is the biggest threat, this configuration can provide the best of both worlds. The downside is that the update rate is usually reduced to alternating sweeps. With hazardous weather anywhere in the area, information should be updated every sweep. Also, if higher priority information should be displayed — terrain for instance — it may not be a good idea to use more than one display for weather radar information.

Finding Your Strategy

How will you know which strategy will work best for you or your flight department? By taking advantage of the learning opportunities that present themselves on the easy days as cells approach and then pass harmlessly abeam. Observe how cells look when they are embedded in the ground returns and then how they eventually march out of the ground returns. Learn to read the ground returns and observe radar shadows. Note how a cell located behind an intervening cell may be understated, weaker than its true intensity (radar energy had to make a two-way trip through the intervening cell).

Also, try using "traditional techniques" and notice how hazardous cells will often weaken in intensity on the display as the bottom of the beam begins to approach the radar top. Note how lowering the tilt minimizes overscanning. All flights in good weather are analogous to a scientist's laboratory — an opportunity to try different things, learning what does and does not work so well.

Successfully avoiding cells at night or in IMC hinges on your learned skills. As with any other activity, good intentions don't guarantee success. The only successful strategy for minimizing these weather risks will result from training and practice. And even though mistakes will be made along the way, the key is to make them when the consequences are minimal and then to learn from them. Irrefutably, one of the biggest mistakes to be made is to wait until the outcome of the decision is critical — the threat to the aircraft or those within is at hand — before turning the radar on and start learning.

Remember, in spite of the fact that convective weather can grow at a rate of several thousand feet per minute, thunderstorms do not just suddenly appear at cruise altitudes "with less than two seconds notice." You just have to know how and where to look for them with the radar.

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Fatigue and take-off data... a lethal combination

At 00.03 local time MK Airlines flight 1602 departed Windsor Locks-Bradley International Airport (BDL) for a flight to Zaragoza, Spain with a cargo of lawn tractors. An intermediate stop was made at Halifax (YHZ), where the aircraft landed at 02.12 local time. At YHZ the aircraft was loaded with 53,000 kilograms of lobster and fish. After fueling, the total fuel load was 89 400 kg. The planned take off weight was 353 000 kg. The Boeing Laptop Tool (BLT) was then used to calculate the take-off speeds. Since the software was last used before the take-off from Bradley, it still contained those figures

The airport information and weather was changed to Halifax, but somehow the take-off weight was not changed and remained showing 240000 kg. Take-off performance data were generated, resulting in incorrect V speeds and thrust setting being transcribed to the take-off data card. It is most likely that the crew did not adhere to the operator's procedures for an independent check of the take-off data card, so the erroneous figures went unnoticed.

It was dark, but the weather was fine as the airplane was cleared to taxi to Runway 24 (8800 ft / 2682 m long) for departure. After push back, the aircraft began to taxi, the flaps were extended to 20°, and the horizontal stabilizer was set to 6.1 trim units, where it remained for the duration of the flight. The flight control checks were completed during the taxi. The aircraft entered Runway 24 at Taxiway Delta and backtracked to the threshold.

The aircraft then made a 180° turn to the right and, upon lining up with the runway, the thrust levers were advanced and a rolling take-off was commenced at 06:53:22.

At the start of the take-off roll, the thrust levers were smoothly advanced from ground idle thrust (approximately 1.0 EPR) to take-off power with all final EPR settings indicating between 1.3 and 1.33. The aircraft accelerated through 80 KCAS (06:53:46) approximately 1800 ft (550 m) from the threshold.

At 130 KCAS, the control column was moved aft to 8.4° to initiate rotation as the aircraft passed the 5500-ft (1680 m) mark of Runway 24 (3300 ft / 1010 m of runway remaining). The aircraft began to rotate. The pitch attitude stabilized briefly at approximately 9° nose-up,

with airspeed at 144 KCAS. Because the 747 still had not lifted off the runway, the control column was moved a further aft to 10°, and the aircraft responded with a further pitch up to approximately 11°; initial contact of the lower aft fuselage with the runway occurred at this time. The aircraft was approximately at the 8000-ft (2450 m) mark and slightly left of the centreline. The control column was relaxed slightly, to 9° aft.

The pitch attitude stabilized in the 11° range for the next four seconds, and the lower aft fuselage contact with the runway ended briefly. With approximately 600 ft (185 m) of runway remaining, the thrust levels were advanced to 92 per cent and the EPRs increased to 1.60. With 420 ft (130 m) remaining, the lower aft fuselage contacted the runway a second time.

As the aircraft passed the end of the runway, the control column was 13.5° aft, pitch attitude was 11.9° nose-up, and airspeed was 152 KCAS. The highest recorded nose-up pitch of 14.5° (06:54:24) was recorded after the aircraft passed the end of the runway at a speed of 155 KCAS. The aircraft became airborne approximately 670ft (205 m) beyond the paved surface and flew a distance of 325ft (100 m).

The lower aft fuselage then struck an earthen berm supporting an instrument landing system (ILS) localizer antenna. The aircraft's tail separated on impact, and the rest of the aircraft continued in the air for another 1200 ft (370 m) before it struck terrain and burst into flames.

Airline expansion

MK Airlines Limited has grown significantly during its relatively short history. The company's commercial success and subsequent expansion increased demands in its infrastructure.

The addition of the B747 aircraft added significantly to the Training Department's challenge of meeting the demand for qualified flight crews.

At the same time, flight crew turnover was increasing as individuals found more attractive employment elsewhere. Also, the company's policy of recruiting from southern Africa limited the pool of new potential crew members.

All these factors contributed to a shortage of flight crew required to meet the flying or production demand. This shortage of flight crew increased the potential for increased fatigue and stress among the personnel.

Rest, duty and flight time

Although the Operations Manual stated that flights would not be planned beyond 24 hours, the Crewing Department at MK Airlines Limited routinely scheduled flights in excess of that limit.

There was no effective programme in place to monitor how frequently these planning exceedences occurred, nor was there a program to detect and monitor exceedences beyond the planned duty days.

In the absence of adequate company corrective action regarding these exceedences, crew developed risk mitigation strategies that included napping in flight and while on the ground to accommodate the longer scheduled duty days. This routine non-adherence to the Operations Manual contributed to an environment where some employees and company management felt that it was acceptable to deviate from company policy and/or procedures when it was considered necessary to complete a flight or series of flights.

There is a reasonable limit to the time a flight crew can remain on duty before acute fatigue begins to induce unacceptable human performance deficiencies. This is regardless of the crew composition and the adequacy of the rest facilities on board the aircraft.

Examination of the occurrence crew's work/rest/sleep and duty history indicated that the operating crew would have been at their lowest levels of performance because of fatigue at, or shortly after, their arrival in Halifax. This state of fatigue would have made them susceptible to taking procedural shortcuts and reduced their situational awareness.

This period of low performance would have been present when the take-off performance data were calculated, the before-flight standard operating procedures were not followed, and the inadequate take-off performance was not recognized.

The company's flight and duty scheme allowed flights to be scheduled up to 24 hours with only three pilots required. This meant that there would be either only one captain or one first officer in the crew. Because most crew members were only qualified to occupy either the left or right pilot seat, two of the assigned pilots would have to be present for every take-off, departure, arrival, and landing for the entire route.

This resulted in the lone captain or first officer being subjected to a disproportionate amount of flight deck duty and, therefore, more vulnerability to fatigue. For this series of flights, the first officer was the critical crew member in this respect.

The first officer had checked out of the hotel in Luxembourg at 0925 on October 13, but it is known that he was awakened earlier than 0848, perhaps as early as 0630 or 0700. It is probable that he was not in the cockpit for a few hours on the first flight, but it is unlikely that he would have slept or had a good rest because of circadian rhythm effects.

As other MK Airlines Limited flight crews indicated, it was not easy to get rest on the flight to Bradley International Airport because of the time of day. The flight from Bradley to Halifax took 1 hour 9 minutes, and the first officer would have been in the cockpit during this flight. Therefore, he would likely have been the most fatigued pilot.

The aircraft was on the ground at Halifax International Airport for 1 hour 42 minutes.

Twice during this time, it was noted by ground personnel that the first officer was not in the cockpit, and it was common for flight crew to nap or rest if the turnaround time was long enough.

It is likely that he took a nap between the time the take-off performance data was calculated and when he was required to be back in the cockpit to prepare for the departure.

If the first officer had been sleeping while the aircraft was on the ground in Halifax, he would have been susceptible to sleep inertia for 10 to 15 minutes after waking up. As a result, he would have been less alert than usual when he first entered the cockpit, the period when the performance data would have been set from the take-off data card information.

In addition, if the captain had carried out some of the first officer's pre-flight duties to allow him to sleep, this would have further removed the first officer from the cockpit environment and decreased his situational awareness.

At the time of the occurrence, MK Airlines Limited rest, duty and flight time scheme was one of the least restrictive among ICAO signatory states. The company's increase of the maximum flight duty time for a heavy crew from 20 to 24 hours also increased the potential for fatigue.

Findings as to causes and contributing factors:

1. The Bradley take-off weight was likely used to generate the Halifax Take-off performance data, which resulted in incorrect V speeds and thrust setting being transcribed to the take-off data card.
2. The incorrect V speeds and thrust settings were too low to enable the aircraft to take off safely for the actual weight of the aircraft.
3. It is likely that the flight crew member who used the Boeing Laptop Tool (BLT) to generate take-off performance data did not recognize that the data were incorrect for the planned take-off weight in Halifax. It is most likely that the crew did not adhere to the operator's procedures for an independent check of the take-off data card.
4. The pilots of MKA1602 did not carry out the gross error check in accordance with the company's SOPs, and the incorrect take-off performance data were not detected.
5. Crew fatigue likely increased the probability of error during calculation of the take-off performance data, and degraded the flight crew's ability to detect this error.
6. Crew fatigue, combined with the dark take-off environment, likely contributed to a loss of situation awareness during the take-off roll. Consequently, the crew did not recognize the inadequate take-off performance until the aircraft was beyond the point where the take-off could be safely conducted or safely abandoned.
7. The aircraft's lower aft fuselage struck a berm supporting a localized antenna, resulting in the tail separating from the aircraft, rending the aircraft uncontrollable.
8. The company did not have a formal training and testing program on the BLT, and it is likely that the user of the BLT in this occurrence was not fully conversant with the software.

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