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The Official Publication of THE UNITED KINGDOM FLIGHT SAFETY COMMITTEE ISSN: 1355-1523 AUTUMN 2010

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.

Editorial Office:
The Graham Suite, Fairoaks Airport, Chobham, Woking, Surrey. GU24 8HU
Tel: 01276 855193 Fax: 01276 855195
e-mail: admin@ukfsc.co.uk
Web Site: www.ukfsc.co.uk
Office Hours: 0900 - 1630 Monday - Friday

Advertisement Sales Office:
UKFSC
The Graham Suite, Fairoaks Airport, Chobham, Woking, Surrey GU24 8HU
Tel: 01276 855193 Fax: 01276 855195
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Web: www.wokingprint.com

Front Cover Picture: An Airbus A380 escorted by an F18 of the Swiss Air Force. © Swiss Air Force.

'If you think ground handling training is expensive, try looking at the cost of aircraft damage and delays'

by Rich Jones, Chief Executive UKFSC

In preparation for the last UKFSC Safety Information Exchange, Members were asked to identify their company's top three safety concerns from the past year and share them with the Committee during the meeting. With over 40 companies responding, this exercise produced a invaluable list of current safety issues which ranged from strategic global to operational local as well as identifying a variety of topics, depending on the perspective and role of the company in question – airline, airport, manufacturer or MRO.

One major, widely-held safety concern is the number of ramp and stand area incidents and the significant cost in human and equipment damage being caused. In several safety forums prior to our meeting, I had heard an oft quoted statistic which suggested that over $4Bn worth of aircraft damage per year can be attributed to incidents in and around the ramp areas of the world's airports.

Whilst this cost is a serious worry in itself, this situation is further exacerbated by the fact that some of this damage to the aircraft's integrity goes unreported by the perpetrator at the time, either through lack of appreciation, fear of disciplinary action or deliberate intent. Moreover, one European airline association through analysis of its Members' reports concluded that around 30 aircraft each year get airborne with significant unreported damage, which is only discovered once airborne or on returning to home base. For the majority of today's commercial transport aircraft, damage detection and discovery can be reasonably straightforward since signs of collision can be fairly easily detected on metals and alloys with the naked eye. However with the rapidly increasing introduction of carbon fibre materials into aircraft fuselage and wing sections, this brings a much greater challenge to damage detection. The outer shell of a carbon fibre body can tend to spring back into shape after a collision without witness marks, but any de-lamination within the hidden layers and structure are not so easily identified, nor is the consequent degree of strength loss. This also assumes that the perpetrator wishes to declare it and has been trained to understand the potential for internal damage to these new types of structure.

This significant level of wasted resource may not come as a real surprise to many safety professionals across the commercial aviation sector, but it is no less disappointing that we seem unable to make any serious inroads towards reducing it. There are some very welcome initiatives underway. The UK CAA Ground Handling Operations Safety Team has developed an excellent package of training guidelines for ground handling service providers. Encouragingly, these have also been adopted and promoted by the European Commercial Air Safety Team. Importantly, the guideline package was closely aligned on the various elements sought by the IATA Safety Audit of Ground Operations programme; this was a deliberate strategy in an attempt to ensure a co-ordinated and universal approach and to set a standard based on good practice. Whilst the pursuit of this comprehensive and widely endorsed approach to ground safety is a very positive step, there remain further serious challenges to delivering it effectively. First, the commercial pressures exerted by airlines and resulting competition amongst ground handling service providers is causing them to pay their ramp workers poor wages which, in turn, inevitably attracts less capable and qualified candidates. I have heard it said that a survey of ramp workers at one European airport revealed an average reading age of nine. And what is more, this level of skill was not in english.

Second, and particularly amongst the more seasonally effected airports, the rapid throughput of temporary and part time workers makes the establishment of a well-trained and motivated work force extremely difficult to achieve. Directly and indirectly, delivery of effective training does cost money and is readily apportioned to the bottom lime. I wonder how many airlines place the provision of a well trained and experienced work force to handle their expensive aircraft in a safe and efficient manner above the lowest available upfront cost of the ground handling contract? Equally, I wonder how many ground handling companies attempt to assess and then balance costs resulting from delays and damage with their investment in training and retention of ground handlers on the front line?

In the case of ground handling, the mantra of 'If you think safety is expensive, try having an accident' could be usefully adapted to 'If you think ground handling training is expensive, try looking at the cost of aircraft damage and delays'. Seeking to understand the real costs of damage and delays generated by ground handling services is important, but there is a related issue to consider. Another absolutely key component of safe ground handling provision is the establishment of a culture of open and honest reporting of errors, which only a professional, well-trained work force can really develop. Currently, reporting of ground handling incidents is poor, which means that lessons are not learned and that the effectiveness of a company's Safety Management System is undermined.

In a nutshell, effective training and culture of open reporting are the means by which the ground handling performance can be improved and damage and delay costs addressed. However, these can amount to nought if commercial pressures and inadequate ramp supervision enable short cuts to be taken on the ramp. Therefore, I am fast reaching the conclusion that the only way to grip ground handling standards is to subject them to regulation. The opportunity to achieve this, at least in Europe, may eventually come to fruition. EASA has a remit from the European Council in its extension into aerodrome regulation which states that airport operators are to be responsible for the safe operations of ground handling service providers. There is little in the way of detail at this early stage, but it is vital that this opportunity to place the regulatory spotlight on ground handling safety is grasped firmly and the necessary discipline imposed by the introduction of proper oversight, training and supervision on ground handling service provision.

focus ON COMMERCIAL AVIATION SAFETY

Flight Data Monitoring – The Greatest Safety Enhancement?

by Capt. Tony Wride, Monarch Airlines

During my time as Head of Safety Management for Monarch Airlines I have been working closely with the company that provides our Flight Data Monitoring (FDM) software to develop it to fulfil our safety needs. By working with the software company major enhancements have occurred to enable me, as the airline Safety Manager, to be more effective at maintaining safety. As a result of this close relationship, (No we are not married!), I was asked by them to attend the recent FAA "Shared Vision of Aviation Safety" in San Diego to give the American aviation community a presentation on how we manage safety "across the pond"! I also had the opportunity to hear what the Americans were doing and also find out how far behind Europe some of them are! I couldn't believe that FDM was not mandated by the FAA and that one airline seemed pleased that they were monitoring 15% of their aircraft!

FDM, or FOQA (Flight Operations Quality Assurance) if you prefer, is now the major Flight Safety tool in helping prevent incidents or tragic accidents but despite this tragic accidents still occur as seen in the recent crash in Pakistan. For most of the World FDM (FOQA) is mandated on large commercial aircraft and it could be argued that not having an effective FDM system in an airline as part of its Safety Management System is exposing that airline to a serious risk. The scenario I gave the attendees at the "Shared Vision" conference was; Imagine being in court with a clever lawyer asking the question "So there was a safety programme that could have identified that Captain X had developed an incorrect flying technique which was the cause of the accident yet you chose not to use that programme?" Even Perry Mason might have a job countering that argument!

Initially the pilot community was very much against having the 'spy in the cockpit' but most pilots, certainly those in the UK, now appreciate that the system is there to protect them and look after their jobs. Ok, have just thrown another hand grenade at the pilots out there reading this? What I said is a fact! The FDM system is there, if used properly, to protect the pilots because what it's encouraging is adherence to Standard Operating Procedures (SOPs), which I prefer to call Safe Operating Procedures. If every pilot in the world flew their aircraft as per SOPs I'm sure the accident rate would drop dramatically. A bold statement perhaps but look at the recent accidents that have occurred that have ended up laying the blame on the pilots for not following SOPs.

I have seen and heard stories from other Safety Managers of some amazing events that make you ask the question "What was the pilot thinking?" Somebody levelling the aircraft shortly after take off, apparently avoiding birds, so they end up flying past the crew hotel! Somebody getting high on an approach and doing S turns to finally roll the wings level at 120ft! Somebody doing a positioning flight and rolling to over 60 degrees angle of bank during the departure! Somebody doing a visual approach with a constant turn from downwind to roll the wings level at 50ft over the threshold! All of these things would be fine in a military aircraft or during a display but not in a commercial aircraft with a large number of fare paying passengers in the back! In these incidents the pilots were clearly not following SOPs and definitely increasing the risk to the aircraft and all aboard.

The above incidents are extremes and the FDM systems of the airlines concerned picked up these events and alerted the Safety Team. Obviously the pilots concerned "had their collar felt" but I still find it hard to believe that anybody, let alone a commercial airline pilot, could be so stupid as to think they could "get away with it"! It is perhaps this very small group of pilots, who do their own thing or arrogantly think that they are better than they actually are, that FDM was introduced to combat.

If you want to read an interesting article and watch an interesting video Google "1994 Fairchild Air Force Base B-52 crash". This tragic accident was caused by the pilot "Bud Holland" flying the aircraft beyond its limits and loosing control. The accident board stated that Bud Holland's personality significantly influenced the crash sequence. USAF personnel testified that Holland had developed a reputation as an aggressive pilot who often broke flight safety and other rules. The rule breaking included flying below minimum clearance altitudes and exceeding bank angle limitations and climb rates. In other words not following SOPs!

Fortunately the majority of pilots go to work wanting to do a professional job to the best of their ability. Most of the time these pilots rigidly adhere to SOPs, because they are professional, and they get satisfaction from doing a good job. Occasionally these pilots might trigger an FDM event because of an unintentional error or due to external influences like poor ATC control. But there is another area where FDM can help these 'normal' pilots and prevent accidents. If an FDM system is adequately resourced and given the agreement by the pilot community then it is possible to identify an unintentional 'bad' technique which can then be corrected before an accident occurs.

In the Monarch FDM system we were able to identify a number of pilots who unintentionally, and due to the design of the Airbus rudder pedals, were applying slight brake pressure during the take off roll. These pilots were advised of the unintentional error they were making and corrected their technique. As a result the number of "Brake on Take Off" events dramatically reduced. I use this as a classic example of Pro-Active FDM and to argue the case for FDM protocols to be less restrictive.

In the 'Total Safety Management System' FDM is a key tool that must be used to its full capability to maintain safety. Old fears about the system need to be 'laid to rest' and the pilot community needs to appreciate the benefits of the FDM system rather than think that it is 'out to get them'!

Close Call in Khartoum

Confusion reigned when an A321 was flown below minimums in a sandstorm

by Mark Lacagnina

A navigation fix that was not where the flight crew thought it was, omission of standard callouts and a mix-up in communication about sighting the approach lights were among the factors involved in an unstabilized approach that was continued below the minimum descent altitude (MDA) in nighttime instrument meteorological conditions (IMC) at Khartoum, Sudan, on March 11, 2005.

The Airbus A321 “came hazardously close to the ground” before the crew realized their mistake and initiated a go-around, said the U.K. Air Accidents Investigation Branch (AAIB) in its final report on the serious incident. A few seconds later, when the aircraft was 125 ft above ground level (AGL), the terrain awareness and warning system (TAWS) generated a “TERRAIN, PULL UP” warning.

The report said that if the go-around had been initiated six seconds later, the aircraft likely would have struck the ground 1.5 nm (2.8 km) from the runway threshold. The TAWS warning occurred between 3.4 and 5.1 seconds after the go-around was initiated.

“Given that procedural triggers to go around had not been effective, it is of concern that the warning system may not have provided sufficient alert time to prevent an impact with the ground,” the report said.

The TAWS was found to have functioned according to applicable design and installation standards. The system received position information from the A321’s flight management and guidance system (FMGS) based on multi-sensor area navigation calculations.[1] The report said that position information received directly from an on-board global positioning system (GPS) receiver is more accurate and results in more timely warnings.

Without a direct GPS feed, TAWS sensitivity is reduced when the aircraft is near the runway to prevent nuisance warnings that might be caused by less accurate position information. If the system in the incident aircraft had received position information directly from the on-board GPS and incorporated the latest software changes, a “TOO LOW, TERRAIN” warning likely would have been generated when the aircraft was at 240 ft AGL. “The current TAWS standards undoubtedly were appropriate at the time of implementation, and statistics show that they have significantly reduced the CFIT [controlled flight into terrain] risks, most likely saving many lives,” the report said. “However, operational experience of indirect GPS installations that do not directly feed GPS quality data to the TAWS ... has highlighted problems that have been addressed by the TAWS manufacturers but that are not required to be implemented.

“In essence, the CFIT protection technology has improved, but the required minimum TAWS standards have not. Thus, significant improvements in aviation safety in this area are available but not mandated.”

Among recommendations based on the incident investigation, AAIB urged the European Aviation Safety Agency to work with industry on a review of TAWS design and installation standards “with particular emphasis on the timeliness of alerting when close to the runway” AAIB said, “Revisions to these standards arising from this review should apply [retroactively] to all aircraft currently covered by the TAWS mandate.”

Airbus A321-200

The A321 is a stretched version of the A320. The A321-200 has more fuel capacity, a higher takeoff weight and greater range than the -100. The incident airplane is an A321-231 that was built in 2002; it has International Aero Engines V2533-A5s rated at 146.8 kN (33,000 lb thrust), a maximum takeoff weight of 89,000 kg (196,209 lb) and a maximum landing weight of 79,000 kg (174,163 lb).
Source: Jane’s All the World’s Aircraft

Sandstorm

The British Mediterranean Airways flight had originated in Amman, Jordan, at 2130 coordinated universal time (UTC; 2330 local time) with 19 passengers and eight crewmembers.[2] The commander, 46, had 7,400 flight hours, including 3,700 flight hours in type. The copilot, 39, had 4,700 flight hours, including 3,200 flight hours in type.

“The weather forecast for Khartoum, obtained before departure, had reported gusting northerly winds and reduced visibility in blowing sand,” the report said. “During the cruise, and once they were in Sudanese airspace, the copilot asked ATC [air traffic control] for the latest weather report for Khartoum.” The controller said that the surface winds were from the north at 20 kt and visibility was 1,000 m (5/8 mi) in blowing sand.

Runway 36 was in use. A notice to airmen advised that the instrument landing system (ILS) was not in service. The commander decided to conduct the VHF omnidirectional radio/distance measuring equipment (VOR/DME) approach. The Khartoum VOR/DME (KTM) is 0.6 nm (1.1 km) south of the Runway 36 approach threshold.

“Neither pilot had previously operated in blowing sand, and both were concerned about the possible implications,” the report said. The pilots found no information about blowing sand in the airline’s operations manual and used information about volcanic ash for guidance.

“As a result, the pilots discussed various possible actions, and the commander chose to select continuous ignition on both engines for the approach,” the report said.

Although reported as blowing sand, the meteorological condition at Khartoum had the characteristics of a sandstorm. “Blowing sand is associated with strong winds which raise the particles above ground level but no higher than 2 m [7 ft],” the report said. “Sandstorms are usually associated with strong or turbulent winds that raise particles much higher.” The operations manual recommended that pilots avoid flying in a sandstorm whenever possible.

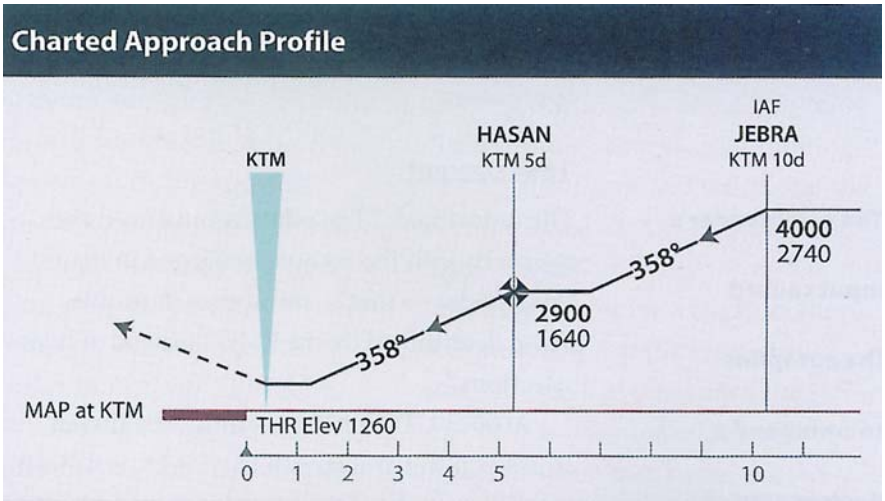


Figure 1

KTM = Khartoum VOR/DME (VHF omnidirectional radio/distance measuring equipment); d = DME distance (nm) from KTM; IAF = initial approach fix; THR Elev = Runway 36 approach threshold elevation; MAP = missed approach point

Source: U.K. Air Accidents Investigation Branch

Managed Approach

Another check with ATC on weather conditions at the airport indicated that visibility had improved to 3,000 m (2 mi). The commander decided to conduct a managed nonprecision approach (MNPA) to Runway 36. "This type of approach requires the autopilot to follow an approach path defined by parameters stored in the aircraft's commercially supplied [FMGS] navigation database," the report said.

At the time, however, the airline was in the process of developing MNPA procedures and had received authorization from a U.K. Civil Aviation Authority (CAA) flight operations inspector to conduct managed approaches only in visual meteorological conditions.

The commander had conducted managed approaches while flying for another airline. "Therefore, [he] did not consider it would be a problem, despite the fact that the reported visibility was below VFR [visual flight rules] limits," the report said. "The copilot's acceptance of this decision illustrates that neither pilot [realized] that not all the necessary safeguards were in place to conduct such approaches safely in IMC."

While setting up for the approach, the crew revised the MDA programmed in the FMGS database to 1,650 ft because the airline's standard operating procedures for nonprecision approach required 50ft to be added to the published MDA.

The pilots were not aware that a discrepancy existed between the location of the final approach fix (FAF) depicted on their approach chart and the location programmed in the FMGS database. Approach charts and FMGS database updates were provided by different commercial vendors. The chart depicted the FAF, called HASAN, at "KTM 5d" — that is, 5.0 nm DME from KTM (Figure 1). The report said that this location resulted from the 2002 Sudanese *Aeronautical Information Publication (AIP)*, which placed the FAF 5.0 nm from both the runway threshold and KTM. "By interpolating the depicted final approach gradient, the [chart vendor] determined that HASAN was actually 5.6 nm from the runway threshold," the report said. "This coincided with the KTM 5 DME position."

The FMGS database included a 2004 amendment to the *AIP* that placed the FAF 5.0 nm from the runway threshold and 4.4 nm DME from KTM.

"The pilots were unaware of [the] significant discrepancy between the approach parameters on the approach chart and those within the navigation database because they had not compared the two data sets before commencing the approach," the report said, noting that this omission was partly the result of the absence of a formal U.K. CAA policy and clear guidance by the airline on how to conduct managed approaches.

'Late' Descent

The report said, "The pilots commenced the approach with the autopilot engaged in managed modes — that is, the approach profile being determined by the FMGS instead of pilot selections."

At 0025 UTC (0325 local time), the aircraft crossed the initial approach fix, JEBRA, at 4,000 ft, and then completed the procedure turn to the final approach course. During this time, the crew asked ATC for the current visibility and were told that it was between 1,000 m and 1,200 m (3/4 mi). The crew said that the A321 was fully configured for landing and stabilized at the appropriate airspeed when it crossed the 5.0 DME location for HASAN depicted on the approach chart at 2,900 ft, the published minimum altitude for crossing the FAF.
The managed approach was being conducted correctly by the autopilot based on the FMGS data. Thus, the aircraft did not begin the final descent at 5.0 DME, as the pilots expected (Figure 2). "The aircraft began its final descent 0.6 nm later than the pilots were expecting," the report said. "Believing the aircraft was high on the approach, the handling pilot [the commander] changed the autopilot mode in order to select an increased rate of descent."

The commander intended to establish the A321 on a 3.0-degree vertical flight path angle, which was equivalent to a descent rate of about 800 fpm at the selected airspeed. He mistakenly believed that the autopilot was in the track/flight path angle mode. The autopilot actually was in the heading/vertical speed mode, and the commander's input caused the autopilot to command a descent rate of 300 fpm, rather than a 3.0-degree flight path angle.

As the aircraft descended on final approach, it entered the sandstorm, and the crew's forward visibility decreased rapidly. "The commander described the effect of the sand as like watching iron filings flying past the windscreen," the report said. He also noted that the visual effect of the landing light reflecting off the sand was disorienting.

The copilot conducted a distance/altitude check at 4.0 DME and found that the aircraft was about 200 ft above the descent profile shown on the approach chart. "The commander stated that as the aircraft approached 3.0 DME, it became apparent that it was not closing with the vertical profile, and so he increased the rate of descent to about 2,000 fpm," the report said. A few seconds later, he reduced the selected rate of descent to 1,200 fpm. "The pilot's selections resulted in a varying flight path angle that averaged about 4.5 degrees," the report said.

Lights in Sight?

The cockpit voice recorder (CVR) recording of the verbal communication between the pilots during the approach subsequently was overwritten. "It has not been possible to establish exactly what was said between the pilots at this time," the report said. "However, it is apparent that at some stage late in the approach, the commander asked the copilot if he could see the approach lights. The copilot mistook this question to be the commander stating that he could see the lights. As a result, the copilot informed ATC that they could see the approach lights and requested confirmation that they were cleared to land. The commander, hearing the copilot's transmission, took this to mean that the copilot had got the approach lights in sight."

Standard callouts were omitted, and neither pilot had the required visual references in sight as the A321 descended below 1,650 ft — about 390 ft AGL. "Had appropriate calls been made at the critical moments, they would have almost certainly prevented the confusion that allowed the aircraft to continue below MDA without the required visual references," the report said.

The commander looked up and saw lights at the one o'clock position but realized that they were not the approach lights. A note on the approach chart caution pilots against

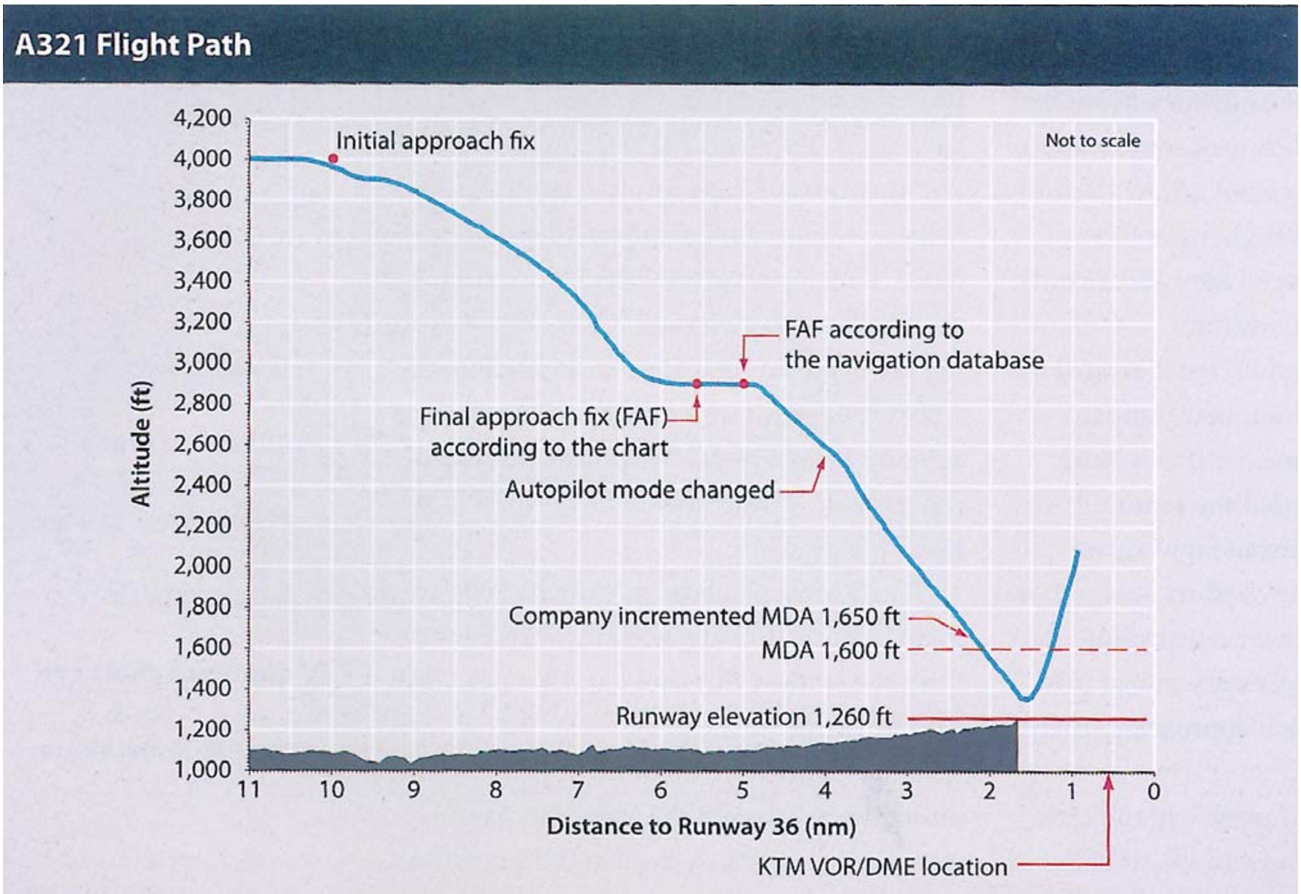


Figure 2

KTM = Khartoum VOR/DME (VHF omnidirectional radio/distance measuring equipment); MDA = Minimum descent altitude

Source: U.K. Air Accidents Investigation Branch "confusing local street and bridge lighting with approach and runway lights."

The misidentified lights and the disorienting effect of the blowing sand prompted the commander to initiate the go-around at about 180 ft AGL—210 ft below the MDA. He advanced the throttles to the takeoff/go-around power setting, which automatically engaged the autopilot go-around mode. During this process, the aircraft sank to 125 ft AGL, where the TAWS "TERRAIN, PULL UP" warning was generated. "The commander reported that he noted the aircraft's attitude was 5 degrees noseup, so he pulled back on his sidestick with sufficient force to disengage the autopilot and increase the pitch attitude to between 17 degrees and 20 degrees nose-up," the report said.

The commander pulled the sidestick about halfway back, instead of all the way back, as required by the emergency procedure for responding to the TAWS warning. He told investigators that he believed he already was "overpitching the aircraft" Nevertheless, the report said, "By nature, any [TAWS] terrain warning requires prompt and decisive action, and the protections built into the aircraft's flight control system allow for the application and maintenance of full back sidestick until the warning ceases."

Two More Tries

During the missed approach, the commander briefed the copilot for another approach. He decided not to conduct another managed approach but to use raw data and selected autopilot modes. "The pilots also decided to leave the landing lights off for this second approach to prevent the disorienting effect of light scattering off the sand." the report said.

During the second approach, the pilots did not have the approach lights in sight at the missed approach point, KTM, and another missed approach was conducted at 0049 UTC. "While carrying out the go-around, the commander could make out the running strobe lights below and stated that the aircraft passed slightly to the right of them," the report said.

The pilots told investigators they became aware that the crew of another aircraft had conducted the ILS approach and landed on Runway 36. However, when they tuned the ILS frequency, they found that a test code was being transmitted, indicating that the ILS must not be used for an approach. The crew decided to conduct another VOR/DME approach.

"While maneuvering, they heard the pilots of another inbound aircraft ask Khartoum Tower to confirm that the visibility was now 200 m [1/8 mi]," the report said. "When this reported visibility was confirmed, the copilot immediately questioned the tower controller about the current visibility at Khartoum. The initial reply from the controller was that the visibility was 900 m [between 1/2 and 5/8 mi], followed quickly by a correction to 800 m [1/2 mi] and then a further correction by the controller to 200 m"

The commander broke off the approach at 4,000 ft and diverted to Port Sudan, where the aircraft was landed without further incident at 0214 UTC (0514 local time).

This article is based on UK. AAIB Aircraft Incident Report No. 5/2007 (EW/C2005/03/02).

Notes

1. FMGS is an Airbus term. Flight management system (FMS) is another term used to describe the equipment.
2. British Mediterranean Airways was founded in 1994 and operated as a British Airways franchise until 2007, when it was acquired by the U.K. airline bmi.

This story is taken from an issue of Flight Safety Foundation's journal, AeroSafety World. A free subscription to the digital version of that publication is available though the signup form on the Foundation's Web site home page, www.flightsafety.org

PBN
Performance Based Technology

First appearing in flightsafety Australia, this article provides a useful account of the benefits available from P B Navigation

Increasingly, airlines around the world are capitalising on the safety, operational and environmental benefits offered by performance based navigation (PBN). *Flight Safety* editor, Margo Marchbank, talks to PBN specialists in Australia and internationally about these navigation procedures and moves towards global harmonisation.

Performance based navigation employs satellite technology for optimal use of increasingly congested airspace. It also allows safer operations into challenging terrain, and increasingly, is being recognised for the operational and environmental efficiencies it brings. PBN encompasses a shift from groundbased navigational aids emitting signals to aircraft receivers, to a system that relies more on the performance and capabilities of equipment onboard the aircraft. Conventional route procedures require an aircraft to follow the ground-based navigational infrastructure in a point-to-point fashion - an uneconomical use of airspace. PBN, on the other hand, fully utilises the onboard navigation capability of modern aircraft, is not tied to the ground based infrastructure and permits the aircraft to fly much more economical routes (for example, polar route, jet streams etc).

Last year, 2009, was a landmark year for performance based navigation, according to the International Civil Aviation Organization (ICAO). Late in 2009, *Flight Safety* spoke to Nancy Graham, head of ICAOs Air Navigation Bureau, and ICAO PBN project manager, Erwin Lassooji, in Montreal. 'As the 36th ICAO Assembly recognised in 2007, when it urged member states to have PBN implementation plans finalised by 2009, we will only be able to realise the full benefits of PBN through global implementation', Graham explained. 'PBN is the single-most important project ICAO has undertaken relating to safety, efficiency and being good stewards of the environment.' PBN delivers safety, environmental and operational benefits according to Graham because 'It's the best technology we have, and it's the best use of that technology'.

The Global PBN Task Force is driving the concerted worldwide push for rapid implementation of performance-based navigation. The Task Force comprises the ICAO, ICAO member states, such as the USA's Federal Aviation Administration and CASA in Australia, industry representation such as the International Air Transport Association (IATA), national air navigation service providers (for example Airservices Australia) manufacturers. and companies designing procedures, such as the American-based Naverus. With the Global PBN Task Force established during 2009, the next task, Graham explained, was to focus on regional groups. 'Implementation has to done on a regional basis. We're looking at "goteams",' she continued, 'to bring together the right kind of skills to support implementation.' The various regional groups have formulated specific timelines for their respective regions, and in early 2010, ICAO is setting up a Flight Procedures Office in Beijing to assist states in the Asia-Pacific region. She acknowledges that implementing PBN is a challenging task, because it is demanding, both technically, and in its performance aspects - flight trials and training. PBN is a 'first step for the regulator, it's a first step for the airlines, and it's a first step for the designers - all these things (the suite of regulations, the training of personnel and having suitably equipped aircraft, the design of appropriate procedures) have to come together, but Graham stresses the committed involvement of the global aviation community.

Implementing PBN is a challenging task, Dirk Noordewier agrees. He is an air transport inspector, and CASA's PBN project manager. 'Worldwide, there are all these, different navigation approvals, with different terminology,' he explains. 'The whole point of PBN is to rationalise these and get consistency. Satellite navigation and satellite comms have enabled aircraft to be self-sufficient, so the bit of land you're over is no longer the issue it used to be.' ICAO has set deadlines for PBN - the primary ones for Australia were the submission of a PBN implementation plan by the end of 2009; and a 2010-2016 timetable for implementation of approaches with vertical guidance (APV).

Australia's PBN implementation plan has been submitted, and addresses navigation authorisations for Australian operators under CASR Part 91U. All the authorisations will align under PBN. ICAO's timetable for approaches with vertical guidance requires member states to have APV implementation 30 per cent complete by 2010, 70 per cent by 2014, and fully complete by 2016. 'APV', Noordewier explains, 'are an ICAO safety initiative with the goal of preventing controlled flight into terrain. APV will be the standard instrument approach - it's our intention that 2D approaches will become a thing of the past. PBN,' he adds, 'is more than just RNP AR.' A focus on RNP AR underestimates the safety and efficiency benefits of Baro-VNAV capability for light aircraft, and APV generally, he contends.

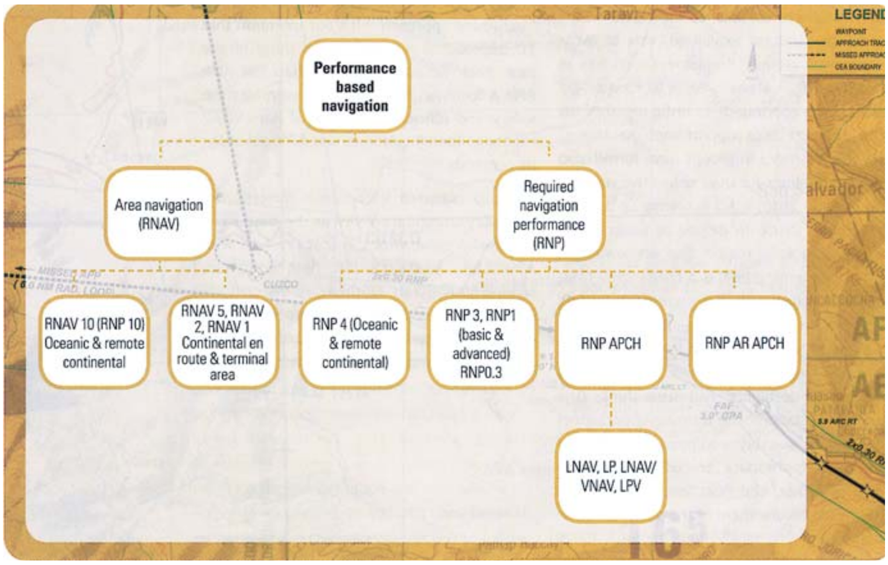
What is PBN?

PBN is an ICAO initiative to harmonise global navigation specifications. This includes all phases of flight-from oceanic and enroute, to terminal and approach procedures. PBN specifications already implemented include RNAV 10 and RNP 4 for oceanic operations, and RNP APCH and RNP AR APCH for approach operations. PBN encompasses two types of navigation specifications: RNAV (aRea NAVigation) and RNP (required navigation performance). Distinctions between the two are difficult to pinpoint accurately -'It's often hard to tell the difference,' Noordewier says. Some identify differing requirements for onboard performance monitoring and alerting as distinguishing RNAV and RNP. Area navigation specifications, for example RNAV5, RNAV1, do not require this. Required navigation performance utilises the aircraft's navigation system to integrate numerous sources of positioning data (e.g. inertial, satellite and barometric data) to provide highly accurate navigation solutions with real-time integrity monitoring and alerting. All RNP specifications require onboard performance and monitoring. In a flight management system (FMS)-equipped aircraft this can be achieved through AAIM (aircraft autonomous integrity monitoring) where the RNP is compared to the actual navigation performance (ANP). In a aircraft utilising an IFR GNSS Navigator this can be achieved through RAIM (receiver autonomous integrity monitoring).

Broadly, RNAV is an equipment-based navigation concept and RNP is a performance-based navigation concept. With RNP, the aircraft has an onboard 'quality management system'. Information from the global satellite system calculates its position from the satellites in view. A timely warning is provided when the quality of that positional solution deteriorates below an acceptable limit, alerting the pilot of the need to discontinue the approach. For example, in the case of an RNP-AR approach to an RNP value of 0.1, we are setting the 'alarm limit' so that should the quality of the navigation solution deteriorate below the threshold of 0.1nm, then the alarm will sound a warning long before the accuracy of navigation is compromised.

RNP APCH & RNP AR APCH

Under PBN harmonisation, all approaches are now classified as RNP navigation specifications. There are two broad categories: RNP APCH and RNP AR APCH. RNP APCH can be either two-dimensional (2D) or three-dimensional (3D) and operate only to an RNP value of 0.3nm. RNP AR APCH is by definition a 3D approach and operates to an RNP value of 0.3nm and below.



There are four types of RNP APCH procedures:

- RNP APCH - LNAV: where lateral guidance is provided by GNSS signal in space (SIS) (currently known as RNAV GNSS procedures);
- RNP APCH - LNAV/VNAV: where lateral guidance is provided by GNSS SIS and vertical guidance is provided by barometric vertical navigation (Baro-VNAV);
- RNP APCH - LP (localiser performance): where lateral guidance equivalent to a localiser approach is provided by augmented GNSS SIS; and
- RNP APCH - LPV (localiser performance with vertical guidance), where lateral and vertical guidance is provided by augmented GNSS SIS.

RNP APCH-LNAV can be considered the simplest RNP approach procedure providing 2D instrument approaches to runways without the need for ground-based navigation facilities. RNP APCH 2D procedures have been flown in Australia for many years, initially identified as GPS/NPA procedures and more recently as RNAV (GNSS) procedures. These procedures are now known as RNP APCH - LNAV.

An RNP APCH may be flown as either a two-dimensional or three-dimensional procedure. Where RNP APCH procedures involve only 2D guidance they are classified as non-precision approaches (NPA); where they have 3D guidance they are classified as approaches with vertical guidance (APV). Therefore RNP APCH NPA and APV can be summarised as:

- NPA:
  - RNP APCH - LNAV
  - RNP APCH - LP
- APV:
  - RNP APCH-LNAV/VNAV, and
  - RNP APCH - LPV.

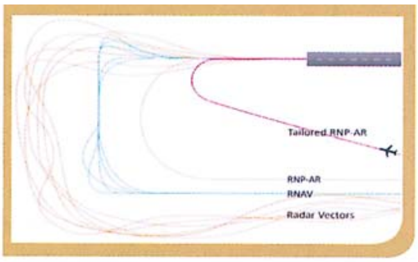
Required navigation performance 'authorisation required', or RNP AR APCH, utilises IRS and GNSS in combination to provide far higher accuracy and performance over an RNP APCH- to quote Naverus, by 'allowing for predetermined, precise, curved flight paths which navigate within an airspace to reduce track miles, conserve fuel, preserve the environment and increase airspace capacity.'

RNP AR APCH Procedures

- operate to RNP values as low as 0.1nm,
- utilise radius to fix (RF) turns, and
- have non-normal events such as engine failure incorporated into the procedure profile.

Australia is in a unique position in implementing PBN technology according to Dirk Noordewier. Australia's high-capacity regular public transport fleet is relatively young, with an average age of around 15 years, and therefore equipped with the appropriate onboard technology. Over 60 per cent of Australia's domestic jet fleet is certified to RNP0.3 or better. Importantly, too, Australia does not have a high-density ground-based nav-aid network. This is on stark contrast to somewhere like the United States, which has an older fleet of legacy aircraft, a high density network of ground-based navigation aids, and

Comparison of approach path with radar vectors. RNAV & RNPAR



RNP approach to Lin Zhi, Tibet, a 95-mile serpentine approach between 17-20,000 ft mountains

therefore a low dependency on global navigation satellite systems (GNSS). 'Many countries don't "get" countries like us,' Noordewier explains. 'We are almost completely bypassing RNAV, and going straight to RNP. The end result is that we're seen as world leaders.' Nancy Graham agrees. 'You're early adapters. Australia's always one of the first to do anything, especially when it comes to safety and efficiency.'

RNP AR & Safety

It was this concern for aviation safety that led to the development of RNP AR - to make flying into airports located in challenging terrain, or with a challenging climate, safer. Juneau, Alaska is a case in point. There, a high mountainous range flanking the Gastineau Channel created challenges for aviation safety. Frequently, operations into the Juneau International Airport runway 08 had been interrupted or delayed because of low visibility and ceilings, and if wind affected runway 08, the opposite runway, 26, was not usable because there was no approach landing aid and associated procedures. These conditions had led to hull accidents and loss of life, as well as cancellations and diversions because of bad weather. In May 1996, Steve Fulton, the founder of US procedures design company Naverus, and Hal Anderson, both pilots and engineers, worked with Boeing navigation system specialists to pioneer RNP at Alaska Airlines. They designed a new RNP approach for the airlines' 737-400 aeroplanes flying into Juneau.

Qantas Airways was also early to recognise the safety benefits of RNP AR for its flights into similarly challenging terrain in Queenstown, New Zealand. High mountains circle the airport; there is no radar; it is a popular tourist destination, and therefore can be a high traffic environment; and the weather can often be a significant factor. The original approach to Queenstown was a circling approach, with an associated risk of controlled flight into terrain. The 737-800s Qantas flies into Queenstown offer advanced capability, so the carrier commissioned Naverus to design an RNP approach for the port. The RNP approach gives the pilot positive three-dimensional guidance all the way to the Queenstown runway. According to Captain Alex Passerini, Qantas technical pilot, 'With RNP, if there's a non-normal event like engine or GPS failure, the crew will have more tools in the toolkit to manage the work, solve the problem, and extract the aeroplane if they're at a low altitude.'

Naverus has also worked with civil aviation authorities, air navigation service providers and airline carriers to implement 'safety-case' RNP at Lhasa in Tibet, and Cusco in Peru. IATA; carrier LAN Peru; and the Peruvian civil aviation authority, DGAC Peru, collaborated on a new RNP approach to Cusco. Guenther Matsschnigg, senior VP, IATA safety operations and infrastructure, argues that the, 'RNP safety advantage is significant, enabling airports located in the most remote areas of the world to have runway-aligned approaches with horizontal and vertical guidance, without having to install, calibrate and monitor expensive ground-based navigation aids'. On 22 May 2009, a LAN Airbus 319 completed its first scheduled RNP procedures flight into Cusco with passengers, the first flight of its kind in South America.

Cusco Airport, the gateway to the popular tourist destination of Macchu Pichu, has an elevation of approximately 10,860ft, and is located at the end of a long valley surrounded by mountains reaching 15,500ft. Ten to fifteen flights a day deliver visitors to Cusco, and in the last three years, unfavourable weather has meant the cancellation or diversion of approximately 200 operations. The new RNP procedures lower the minimum descent altitude from 14,500ft to 11,800ft, almost eliminating such weather-induced delays and cancellations.

RNP AR Savings

However, it soon became apparent that not only did RNP procedures mean improved safety, but they could also deliver significant environmental and operational benefits. The ability to curve the approach path allows the aircraft to be manoeuvred around obstacles and restricted or built-up areas, often resulting in a shorter approach when compared to the zig-zag pattern of conventional ground-based navigation procedures.

Australia's Brisbane Green project highlighted these environmental and operational benefits. In 2007, Airservices Australia introduced RNP AR approach procedures at Brisbane International Airport. Brisbane International Airport is Australia's third busiest, with 21 international and five domestic carriers operating aircraft ranging from turbo-prop and helicopter, to heavy jets. In 2007, there were approximately 173,000 aircraft movements, involving in excess of 17.5 million passengers. Working closely with Naverus, Qantas Airways and CASA, Airservices implemented six RNP approaches and 12 RNP departures.

The Brisbane Green project has three stages:

Stage 1 - involved 33 Qantas 737-800s

Stage 2 - involved Jetstar A320/A321 & Air Vanuatu 737NGs

Stage 3 - Virgin Blue & other international carriers, with additional aircraft types.

The Stage 1 results (2007-2008) were very encouraging. Over 15,500 RNP procedures were conducted, including more than 8,000 approaches. Of these 8,000 procedures, 1612 were flown in instrument conditions, resulting in:

- estimated flight time savings of 4,200 minutes
- estimated 17,300nm reduction in distance flown
- estimated jet fuel saving of more than 200,000kg
- estimated carbon dioxide emission reduction of 650,000kg
- reduced impact of aircraft noise
- reduced delays for non-RNP aircraft, because of shorter arrival times for RNP aircraft.

Qantas-commissioned, proprietary RNP procedures are used at 17 aerodromes in Australia. Former Qantas chief pilot, Chris Manning, is a passionate advocate for RNP, and in a presentation he gave to the 2009 annual Airports & Aerodromes Association conference, argued that 'the use of RNP is imperative if we are to get the greatest efficiencies from the system. We can't impose RNP on current tracks; the tracks can be drawn according to community concerns, but the program needs to continue apace until it is completed.' The community concerns Manning alludes to relate especially to noise levels near airports. The Brisbane trial demonstrated that noise emissions over built-up areas could be minimised by conducting the RNP approach over the river, highway and industrial areas, Chris Henry, general manager of Naverus Australasia, reasons. And in response to the claim from some that RNP concentrates the noise, he replies that 'RNP allows a flexible matrix of paths, so that procedurally, you can "share the noise" by having multiple paths to the same airport.'

The Queenstown approach

While much of the PBN focus has been on approach procedures, in no small part because of their safety implications, it's important not to lose sight of the benefits harmonising global navigation specifications for enroute operations can bring. 'The potential here for significant safety, environmental and economic benefits should not be overlooked,' Dirk Noordewier emphasises. 'There's no point in an aircraft flying RNP4 trans-oceanic, at 30 miles' separation, only to reach an FIR boundary requiring 80 miles' separation,' he explains. 'In the absence of a global standard, air traffic control will group mixed traffic according to the lowest common denominator, so you cannot derive any efficiency benefit from the capability of the aircraft.'

Given that these procedures are still relatively new, he says, 'There is still a reasonably high level of regulatory oversight,' but as these procedures become the default, that will obviously diminish. And in conclusion, he was keen to emphasise that 'PBN is for everyone. It's not just airline stuff. If I've got a GPS IFR navigator in my aircraft, I've achieved RNP 0.3 LNAV standards. That's what it means. I have to have RAIM (receiver autonomous integrity monitoring) if I've got a GPS IFR navigator, and RAIM is performance monitoring'.

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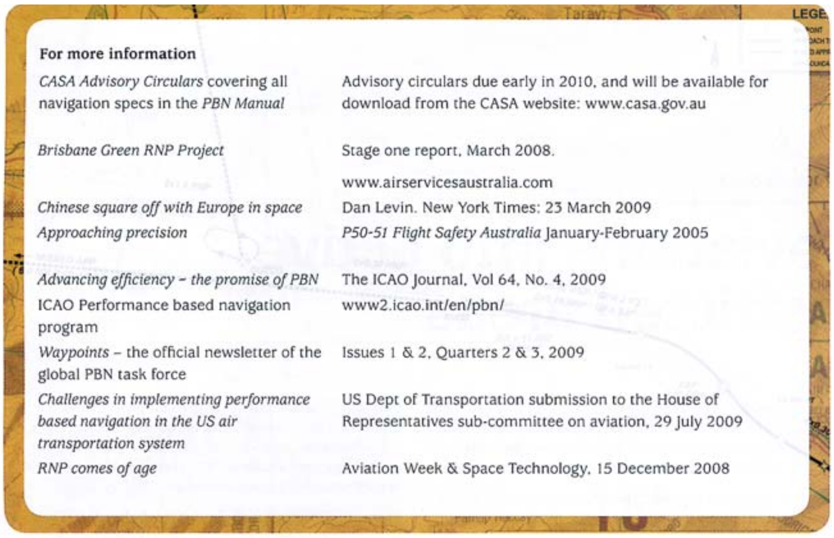


For more information

CASA Advisory Circulars covering all navigation specs in the *PBN Manual*	Advisory circulars due early in 2010, and will be available for download from the CASA website: www.casa.gov.au
Brisbane Green RNP Project	Stage one report, March 2008. www.airservicesaustralia.com
Chinese square off with Europe in space	Dan Levin. New York Times: 23 March 2009
Approaching precision	*P50-51 Flight Safety Australia* January-February 2005
Advancing efficiency – the promise of PBN	The ICAO Journal, Vol 64, No. 4, 2009
ICAO Performance based navigation program	www2.icao.int/en/pbn/
Waypoints – the official newsletter of the global PBN task force	Issues 1 & 2, Quarters 2 & 3, 2009
Challenges in implementing performance based navigation in the US air transportation system	US Dept of Transportation submission to the House of Representatives sub-committee on aviation, 29 July 2009
RNP comes of age	Aviation Week & Space Technology, 15 December 2008

SMS on wheels

A new spin on understanding safety management systems

by Thomas Anthony

For several years, we have sought to explain the safety management system (SMS) concept using the mental model of pillars. Yet, SMS still remains a mystery to many. This is not a reflection on SMS itself but rather on the ways we have sought to explain it.

> *Peter M. Senge, a senior lecturer at the Massachusetts Institute of Technology and founding chair of the Society for Organization Learning, explains the function of mental models as follows:*[1]
>
> *None of us can carry an organization in our minds… What we carry in our heads are images, assumptions and stories… Our mental models determine not only how we make sense of the world, but also how we take action.*

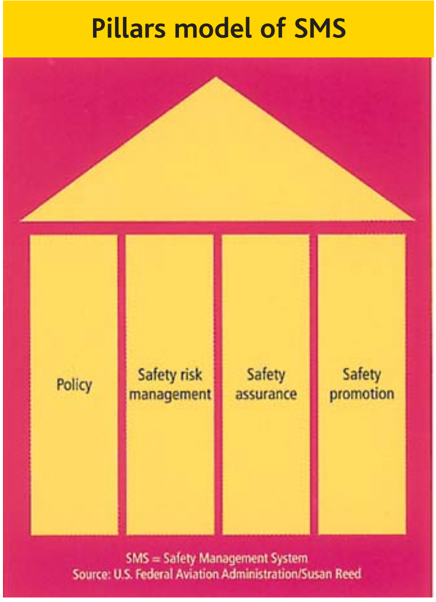
Our mental model of SMS is important not only because it organizes our understanding of SMS but because it directs the action we take and how we move forward with SMS.

With this in mind, let's take a look at the mental model created by the image of pillars (Figure 1). Pillars are singular supportive components of structures such as buildings and temples. They are strong and often clearly identifiable. These positive characteristics of pillars are what led to their widespread use as a mental model for SMS. But, there are other characteristics of pillars that do not fit the concept of SMS. Pillars are static. They are not dynamic; they do not characterize motion or change. While they may be beautiful in structures such as the Panthenon, their function is to support something else. They do not describe the structure as a whole.

For these reasons, the mental model of pillars has taken us just so far with regard to understanding SMS.

What mental model works better? Wheels.

SMS is like a system of wheels or gears, each of which causes the others to turn. Without each one functioning, none of them can turn. This mental model conjures a system in which each element influences the others and in which all the elements must work together for the system to function.


Pillars model of SMS

SMS = Safety Management System
Source: U.S. Federal Aviation Administration/Susan Reed

Figure 1

The three wheels of SMS are:

- Hazard identification;
- Risk analysis and assessment; and,
- Risk mitigation by involved management.

Hazard identification

The first wheel represents all activities of an SMS wherby we collect information and data that help us identify hazards (Figure 2). These activities include hazard reporting systems available to all employees, incident reporting systems, such as an aviation safety action program (ASAP), the U.S. National Aeronautics and Space Administration Aviation Safety Reporting System (ASRS) or the U.K. Confidential Human Factors Incident Reporting Programme (CHIRP), and flight data monitoring systems such as flight operational quality assurance (FOQA) programmes.

Activities that collect information on hazards include surveys, inspections, tests and audits, such as the line operations safety audit (LOSA). These are conducted to identify hazards resulting from operations or performance that do not comply with established standards.

The standards may be regulations, approved procedures or company procedures. There is little room for argument that noncompliant performance represents anything other than a hazard.

In his research, David Huntzinger, now vice president of safety and security for Baldwin Aviation, has found that 60 percent of fatal accidents involved at least one instance of intentional noncompliance with procedure. Additionally, investigations are conducted to identify hazards that contribute to aviation accidents and incidents.

Finally, the hazard identification wheel includes the change management process. James Reason, professor of psychology at the University of Manchester, states, "Change in one guise or another is a regular feature of error-producing situations." Aviation is inherently a dynamic and ever-changing industry that is constantly producing hazards even as it strives to reduce them.

All the activities that are part of the hazard identification wheel provide data on conditions that could result in accidents, incidents or loss in aviation operations. How important are these data-collection processes?

Daniel Maurino, chief of the International Civil Aviation Organization (ICAO) Integrated Safety Management Section, stated it succinctly:

"Without data, you don't have an SMS."

In judging whether an organization has adequate hazard identification channels, we can ask: Are there hazard reporting procedures available for all elements of the organization in which actions may create a hazard that contributes to the accident/incident causation chain?

In short, the hazard identification wheel is the SMS stage that includes all the processes we use to collect hazard information.

ASAP = Aviation Safety Action Programme FDM = Flight Data Monitoring LOSA = Line Operation Safety Audit
Source: Thomas Anthony/Susan Reed

Figure 2

Risk analysis and assessment

The second wheel of the SMS model comprises an essentially different type of activity from hazard identification. In the risk analysis and assessment stage, we process the data that have been acquired in the first stage (Figure 3).

We begin by validating the hazard data to ascertain that the data are true and to gauge the extent to which the hazards exist. Then we analyse the information according to two criteria:

- How severe will the losses be if this hazard occurs?
- How likely is it that the hazard will occur?

So that this risk assessment is done properly, two more conditions must be met. First, a standard by which hazards are assessed is developed and adopted by the organization. This means that all hazards are assessed using the same measure. This is accomplished when an organization develops a risk assessment matrix upon which to base its decisions regarding **likelihood** and **severity**.

Second, however, is the necessity that the organization devote to the risk assessment process individuals who possess the knowledge and expertise necessary to make reasonable and knowledgeable assessments.

The risk assessment matrix is not a "file and forget" tool. It must be applied by high-performing and responsible individuals with expertise from each of the major areas of the organization. Why not say "all major **operational** areas of the organization?" Because hazards can be created by the budget department, the training department and by human resources.

Hazards created by staff offices can be just as deadly as those created by flight operations. Several accident investigations have pointed out that management and administrative practices can present hazards that contribute to the accident causation sequence. Thus, individuals representing all major areas of the organization must participate, as part of the "Safety Action Group," in risk analysis and assessment.

Just as risk assessment depends on hazard identification for data, it also depends on the third wheel, risk mitigation by involved management to make available high-functioning and valuable employees to participate in the risk assessment process.

Additionally, to achieve consistently balanced and objective assessments of risk, a management official with authority over the entire organization should serve as the safety advisor, or head of the Safety Action Group.

The safety advisor is well placed as the secretary of the Safety Action Group to provide expertise, organization and guidance.

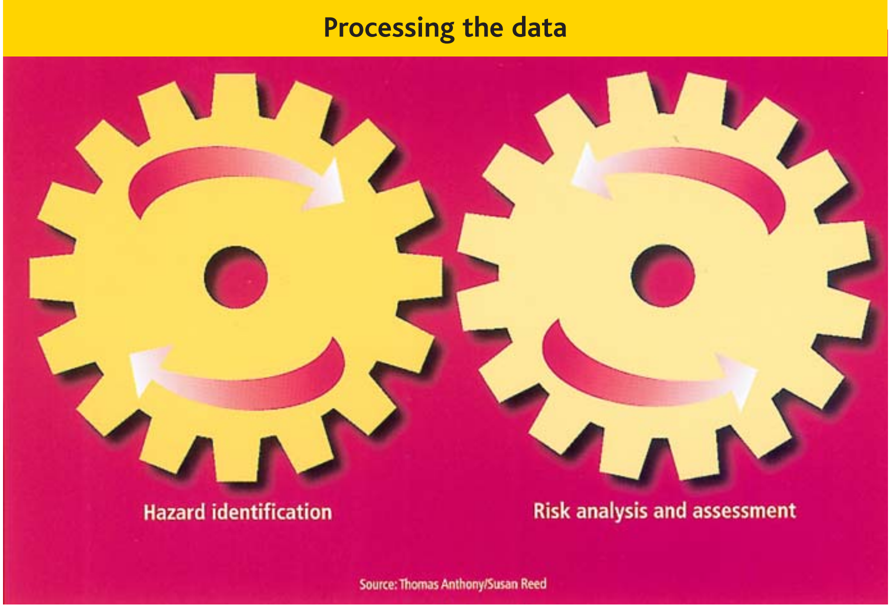
While the discussion of safety management in ICAO Annex 6, **Operation of Aircraft**, and Annex 14, **Aerodromes**, emphasizes top management's accountability for safety, what has been missing from the SMS discussion thus far is that participation in the Safety Action Group risk analysis and assessment process also presents a valuable **opportunity** for management. It is the opportunity to learn about issues that could have the most profound effect upon that particular organization: safety hazards.

Peter Senge, in his book **The Fifth Discipline**, shows how mental models determine how we see our organization, its mission and our role within the organization.

Senge points to a study conducted by Royal Dutch Shell in 1982 that found that of the corporations that made up the Fortune 500 in 1970, one-third of them no longer existed in 1982. The reason for their extinction was in large part due to mental models that did not adapt to changing conditions.

To avoid the same fate, organizations must evolve to become **learning organizations**. Participation by top management in the Safety Action Group is an opportunity for shared learning among all significant elements of the organization.

There is no quicker step on the route to extinction for an aircraft operator than a major accident. Beyond this, participation in the risk assessment process presents an



Source: Thomas Anthony/Susan Reed

Figure 3

opportunity to develop a shared vision that has safety as a core element.

It becomes a mechanism of learning for management, line and staff.

In applying the risk assessment matrix in large organizations that produce a great deal of data, it is desirable to use an automated information system to quantify and classify the hazard data and make initial assessments of risk.

Nevertheless, while it is important to classify and quantify the data being reviewed in the risk assessment process, a measure of judgment and perspective must be applied to the data. As an example, the number of aircraft hijackings that occurred in North America from 1991 to August 2001 was zero. Was it correct then to conclude at the end of that nearly 10-year period that the risk of a hijacking was near zero and therefore no additional mitigation measures were necessary?

No, the 9/11 hijackings proved that such a conclusion was not appropriate. This level of judgment and perspective is best provided by management, that portion of the organization with responsibility over the entire organization.

Involved-Management Action

ICAO Annex 6, Part 1, Section 3.2.5, has it exactly right in stating:

A safety management system shall clearly define lines of safety accountability throughout the operator's organization, including a direct accountability for safety on the part of senior management.

Likewise, U.S. Federal Aviation Administration (FAA) Advisory Circular 120-92, Paragraph 8.b.(3), recognizes the essential character of management involvement and participation in the SMS process:

Management must plan, organize, direct and control employees' activities, and allocate resources to make safety controls effective. A key factor in both quality and safety management is top management's personal, material involvement in quality and safety activities.
Management involvement in the safety process is the essential difference between today's SMS and the risk assessment processes of the past. It is through SMS that safety is granted full consideration among the other principal issues that demand top management's attention.

The third wheel in our SMS mental model is the stage in which action is taken to mitigate unacceptable risk as determined in the previous stage (Figure 4,). There are two preconditions for this stage to be effective. First, the same experienced and knowledgeable individuals must be involved in determining what mitigations will be

(a) effective and
(b) reasonable to implement.

The second precondition is the involvement of top management, because top management has the power to allocate resources for the mitigations and has authority across all competing priorities of the organization.

The third wheel transmits the actions required to mitigate the hazards to the organization.

Lubri-communication

For a system composed of wheels or gears to continue to operate, lubrication is required. In SMS, this lubrication is communication. Without the free flow of meaningful communication, the system will come to a grinding halt. **Communication** means not simply data, but the meaningful back-and-forth sharing of hazard and risk information

Management has a special role in creating an organization that encourages the communication of hazard information. This is done by establishing a **reporting culture** and a **learning culture**. A reporting culture ensures a realistic flow of hazard information and data. A learning culture ensures that hazard/risk information generates reasonable mitigation measures and that the organization internalizes what it has learned. A learning culture underwrites a viable organization.

A learning culture is always asking, Why? Management establishes a reporting culture both by authoring a safety policy statement that supports SMS and by advocacy and personal example.

Management, the driving wheel

SMS = Safety management system
Source: Thomas Anthony/Susan Reed

Figure 4

This means the modelling of behaviours, by example that encourages the free flow of hazard information. A reporting culture cannot be established or sustained in an environment characterized by fear and reprisal.

Although an organization may possess all the component parts of an SMS, the system will have no positive effect unless there is communication. Communication is influenced by mental models. As Senge says, "Two people with different mental models can observe the same event and describe it differently." The perceptions differ because they are viewing the event from the perspectives of two different mental models.

In SMS, the communication intrinsic to the risk assessment stage and the risk mitigation stage forces representatives of different elements of an organization to analyse hazards from single basic perspective: **safety**. In this way, the SMS process stimulates the development of a shared mental model of safety within an organization

Moving forward

Wheels are made for movement. They are dynamic. They imply progress.

They can interact with other wheels, create motion and keep turning. They are the means of moving forward.

The three wheels of SMS work in coordination with each other to produce effective organisational responses to hazards that are inherent and evolving in the aviation environment. The three wheels work together to **collect** hazard information, to **analyse** it in order to ascertain risk and then to act upon this assessment in mitigating unacceptable risk. All components of an SMS fit into one of these three primary functions: collect, analyse and act. For an effective SMS to continue operating, management must create, encourage and support a reporting culture and a learning culture within its organization. Management is the key. It is the driving wheel of the SMS, enabling the rest of the system to create risk mitigation measures.

Beyond the four safety management pillars shown in Figure 1, ICAO Annex 6 and Annex 14 identify the following **five standards** requiring that an SMS:

- Identifies safety hazards;
- Ensures remedial action necessary to maintain an acceptable level of safety;
- Provides for continuous monitoring and regular assessment;
- Aims to make continuous improvement; and,
- Clearly defines lines of safety accountability, including direct accountability for safety for senior management.

The wheels model integrates all these pillars and standards into three basic functions. It has the advantage of making a clear distinction between the collection activities and the analysis activities - that is, the hazard identification stage and the risk analysis and assessment stage. And it emphasizes the role of involved management as the driving wheel of SMS.

Note

1. Senge, Peter M . The Fifth Discipline: The Art & Practice of the Learning Organization. New York: Doubleday/Currency, 2006.

Thomas Anthony is director of the Aviation Safety and Security Program at the Viterbi School of Engineering, University of Southern California.

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Airbus AP/FD TCAS Mode – a new step towards safety improvements

by Paule Botargues – Engineer, Automatic Flight Systems, Engineering

The Traffic Collision Avoidance System (TCAS) has been introduced to reduce the risks associated with mid-air collision threats. Today this safety goal has globally been reached.

However, surprise and stress created by TCAS Resolution Advisories may lead to non-optimum crew response, resulting in a lack of proper communication with ATC, undue aircraft altitude deviations, injuries in the cabin and the jeopardizing of the aircraft's safety.

This article will review the current TCAS interface and procedures. It will then present the Auto Pilot Flight Director (AP/FD) TCAS mode function developed by Airbus, and its numerous operational benefits, which further enhance the pilot interfaces.

Current TCAS interface and procedures

Traffic Advisory (TA)

When the TCAS considers an intruder to be a potential threat, it generates a TA.

This advisory aims at alerting crews to the intruder's position. TAs are indicated to the crew by:

- An aural message, "Traffic, Traffic"
- Specific amber cues on the Navigation Display, which highlight the intruder's position.

No specific action is expected from the crew following a TA.

Figure 1: Navigation Display in case of TCAS TA

Resolution Advisory (RA)

If the TCAS considers an intruder to be a real collision threat, it generates an RA.

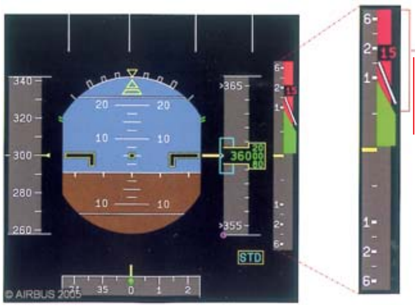
In most cases, the TCAS will trigger a Traffic Advisory before a Resolution Advisory.

RAs are indicated to the pilots by:

- An aural message specifying the type of vertical order (Climb, Descent, Monitor, Adjust...)
- Specific red cues on the Navigation Display materializing the intruder
- Green / red zones on the Vertical Speed Indicator (VSI) specifying the type of maneuver the pilot has to perform.

In order to fly the required maneuver, the pilot selects both the Auto Pilot (AP) and Flight Directors (FD) to OFF, and adjusts the pitch attitude of the aircraft as required, so as to reach the proper Vertical Speed (V/S). This unfamiliar flying technique increases the stress level already induced by the triggering of the Resolution Advisory.

Red area indicating the forbidden verticle speed domain



Audio: "Adjust V/S, Adjust"

Figure 2: TCAS RA HMI without AP/FD TCAS mode

AP/FD TCAS mode concept

Airbus has carried out an in-depth analysis of:

- Needs expressed by airline pilots
- Human factor studies linked to the TCAS system
- Recommenclations given by airworthiness authorities.

This resulted in the development of a new concept called AP/FD TCAS guidance, via the Auto Flight System (AFS), to support pilots flying TCAS RAs.

The AP/FD TCAS mode is a vertical guidance mode built into the Auto Flight computer. It controls the vertical speed (V/S) of the aircraft on a vertical speed target adapted to each RA, which is acquired from TCAS.

With the Auto Pilot engaged, it allows the pilot to fly the TCAS RA maneuvre automatically.

With the Auto Pilot disengaged, the pilot can fly the TCAS RA maneuvre manually, by following the TCAS Flight Director pitch bar guidance.

It has to be considered as an add-on to the existing TCAS features (traffic on Navigation Display, aural alerts, vertical speed green / red zones materializing the RA on the Vertical Speed Indicator).

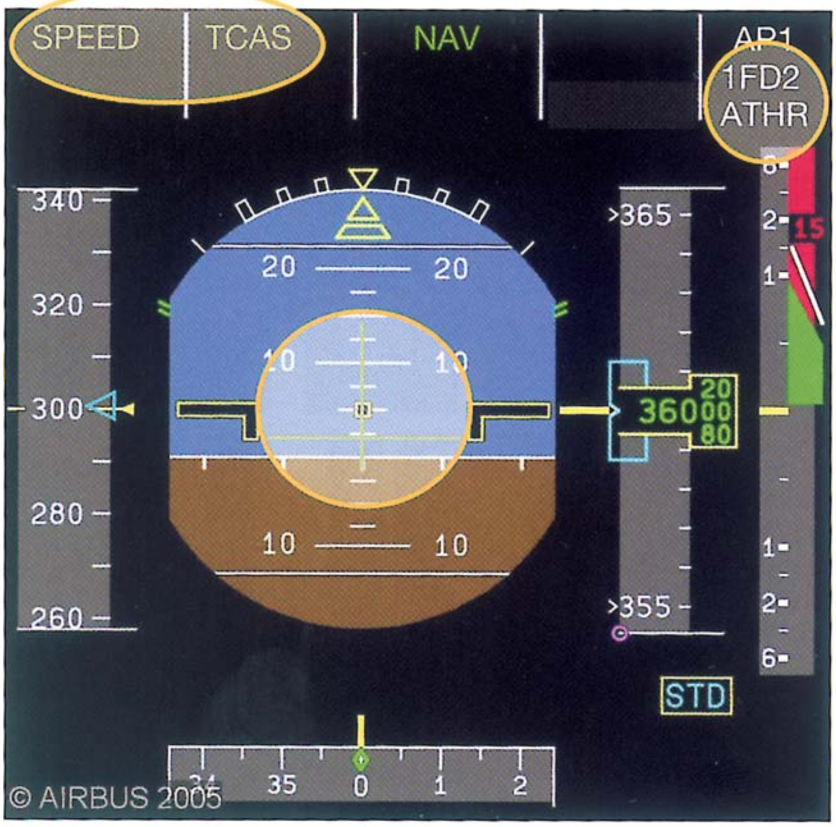
In case of a TCAS RA, the AP/FD TCAS mode automatically triggers the following:

- If both AP and FDs are engaged, the AP/FD vertical mode reverts to TCAS mode, which provides the necessary guidance for the Auto Pilot to automatically fly the TCAS maneuver.
- If the AP is disengaged and FDs are engaged, the TCAS mode automatically engages as the new FD guidance. The FD pitch bar provides an unambiguous order to the pilot, who simply has to centre the pitch bar, to bring the V/S of the aircraft on the VS target (green zone)
- If both AP and FDs are OFF, the FD bars will automatically reappear with TCAS mode guiding as above.

Note: At any time, the crew keeps the possibility to disconnect the AP and the FDs, and is capable to respond manually to a TCAS RA by flying according to the "conventional" TCAS procedure (i.e. flying the vertical speed out of the red band).

The AP/FD TCAS mode will behave differently depending on the kind of alert triggered by the TCAS:

- In case of Traffic Advisory (TA), the AP/FD TCAS mode is automatically armed, in order to bring crew awareness on the TCAS mode engagement if the TA turned into an RA.
- In case of Corrective RA ("CLIMB", "DESCEND", "ADJUST", etc aural alerts), the aircraft vertical speed is initially within the red VSI zone. The requirement is to fly out of this red zone to reach the boundary of the red / green V/S zone.



Audio: "Adjust V/S, Adjust"

Figure 3: PFD upon a Corrective TCAS RA with AP/FD TCAS mode

Consequently:

- The TCAS longitudinal mode engages. It ensures a vertical guidance to a vertical speed target equal to the red / green boundary value (to minimize altitude deviation) + 200 ft/min within the green vertical speed zone, with a pitch authority increased to 0.3g.

- All previously armed longitudinal modes are automatically disarmed, except the altitude capture mode (ALT*) in case of an "ADJUST V/S" alert. This prevents an undue altitude excursion: indeed, in this type of RA, reaching O ft/min is always safe, as this value is never within the red vertical speed zone. Therefore, if the altitude capture conditions are met, the TCAS mode will safely allow to capture the targeted flight level.

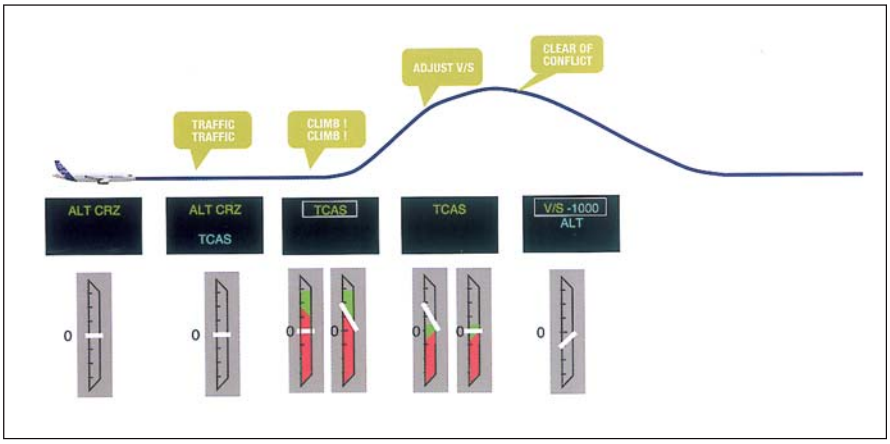


Figure 4: FMA and VSI during a TCAS sequence with AP/FD TCAS mode

- The Auto Thrust engages in speed control mode (SPEED/MACH) to ensure a safe speed during the maneuver.

- The current engaged lateral mode remains unchanged.

■ In case of Preventive RA (e.g. "MONITOR V/S" aural alert), the aircraft vertical speed is initially out of the red VSI zone. The requirement is to maintain the current vertical speed.

Consequently:

- The TCAS longitudinal mode engages to maintain the current safe aircraft vertical speed target.
- All previously armed longitudinal modes are automatically disarmed, except the altitude capture mode (ALT*). Indeed, as for an "ADJUST VS" RA, levelling-off during a Preventive RA will always maintain the vertical speed outside of the red area. So if the altitude capture conditions are met, the TCAS mode will allow to safely capture the targeted level, thus preventing an undue altitude excursion.

- The Auto Thrust engages in speed control mode (SPEED/MACH) to ensure a safe speed during the maneuver.

- The current engaged lateral mode remains unchanged.

■ Once Clear of Conflict, vertical navigation is resumed as follows:

- The AP/FD longitudinal mode reverts to the"vertical speed" (V/S) mode, with a smooth vertical speed target towards the FCU target altitude. The ALT mode is armed to reach the FCU target altitude (ATC cleared altitude)

- If an altitude capture occurred in the course of a TCAS RA event, once Clear of Conflict, the AP/FD longitudinal mode reverts to the altitude capture (ALT*) or to the altitude hold (ALT) mode

- The lateral mode remains unchanged.

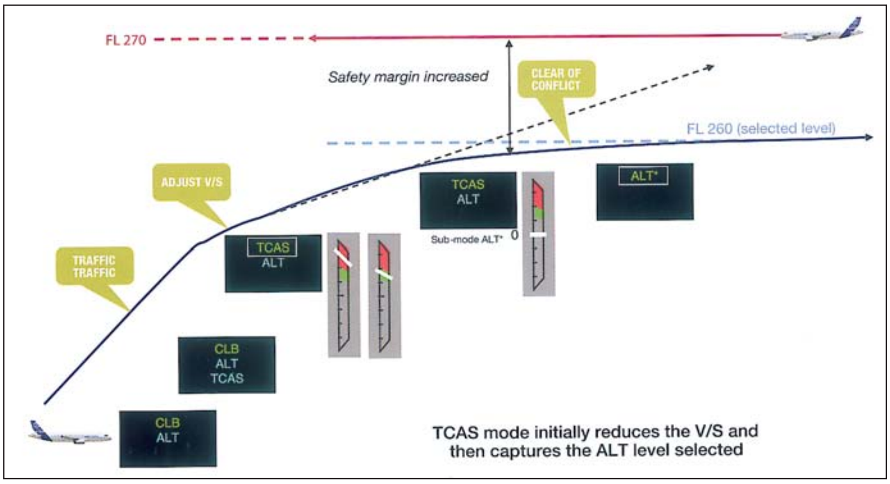


Figure 5: Safe altitude capture in TCAS mode

Operational benefits

The operational benefits of the AP/FD TCAS mode solution are numerous; the system addresses most of the concerns raised by in-line experience feedbacks:

- It provides an unambiguous flying order to the pilot
- The flying order is adjusted to the severity of the RA; it thus reduces the risks of overreaction by the crew, minimizes the deviations from trajectories initially cleared by ATC, and adapts the load factor of the maneuvre
- The availability of the AP/FD TCAS mode makes it possible to define simple procedures for the aircrews, eliminating any disruption in their flying technique: the procedure is simply to monitor the AP, or to manually fly the FD bars, when the TCAS mode engages, while monitoring the VSI.

By reducing the crews' workload and stress level, the AP/FD TCAS mode should therefore significantly reduce:

- Inappropriate reactions in case of Resolution Advisory (late, over or opposite reactions)
- Misbehaviours when Clear of Conflict
- Lack of adequate communications with ATC.

Note: For ATC controllers, the AP/FD TCAS mode is totally transparent in terms of expected aircraft reactions.

The AP/FD TCAS mode was demonstrated to a large panel of pilots from various airlines, and was perceived by them as a very simple and intuitive solution. It was deemed to be consistent with the Airbus cockpit philosophy and Auto Flight system.

All agree that the AP/FD TCAS mode represents a safety improvement.

Certification schedule

The certification of the AP/FD TCAS mode function is expected:

- On the A380: by May 2009
- On the A320 family:
  - with CFM engines, by end 2009
  - with IAE engines, by July 2010
- On the A330/A340, depending on the aircraft type, from the beginning of 2010 (A330 PW/RR) to the end of 2011 (A340-500/600).

The certifcation dates for all required retrofit standards are not yet frozen.

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Assets and Lurking Threats – A view on Training and Safety

by Captain John Bent – Article first published in The Journal for Civil Aviation Training

Airline technology has become more reliable and fail-safe, which should have driven down the accident rate. Instead there seems to be an increasing rate of human failure, which is now more exposed in the man-machine system.

"Recent research shows pilot training is the best investment against catastrophic accident risk" – UK Civil Aviation Authority Study 2008

Since August 2005 there have been many airline accidents where crew training may have been a contributory factor. There were nine to mid-2006, seven from mid-2007 to mid-2008, 12 from mid 2008 to mid-2009, and four since mid-2009. The five-year data remain worrying and may be difficult to explain by relating exclusively to system expansion.

From a total of 37 airline accidents since August 2005, 30 or more may be found to have had human factors at their core. In conflict with advances in airliner technology:

- Training programs have generally declined in relevance, volume and duration;
- Rapid growth has lowered average experience levels;
- Fewer military trained pilots are entering airlines, diluting deep handling skills;
- Motivation levels for a piloting career have changed.

Following accident investigations, crew training often features as an important corrective strategy. Sometimes the "blame and train" solution is apphed instead of a deeper look into systemic and dormant factors within an organisation, aimed at more permanent solutions.

Perceptions

While current challenges are well understood by training professionals, there may be significant perception differences at executive level. The robustly regulated airline environment is designed to protect the system and largely does a good job. But aviation regulations cannot effectively keep up with this rapidly advancing industry.

For example, from 1947 to 2006, when airlines moved from turboprops to jets, thus doubling speed and complexity, airline pilot training requirements hardly changed.

For airline executives under ever increasing pressures to reduce costs, regulators still provide a perceived "security blanket". Under cost pressures, the volume and quality of training delivered to crews may have shrunk to regulatory minimums, sometimes seen as budgetary maximums - "We meet legal requirements, don't we?"

From the ICAO Safety Management Manual (SMM), AN/460 (2006): "Weak Management may see training as an expense rather than an investment in the future viability of the organisation".

A survey conducted by CAPA in 2009 asked airline managements about their current concerns and priorities. Their answers were as follows (% respondent priorities): demand (76%), raising capital (62%), oil price volatility (58%), non fuel operating costs (40%), availability of skilled resourses (15%), technology implemental issue (11%), quality of training (2%).

While these responses are understandable from a purely business perspective, the lack of awareness of the importance of training quality is on interest from a safety management viewpoint.

Volatile

An identified need for training improvements, combined with an apparent lack of executive awareness of this need, combine to produce a volatile mixture in the safety system. The training pilots receive today will reside in the airline system as either a safety asset or lurking threat for decades to come. There is evidence from recent accident summaries that we are seeing the latter already. It is against this backdrop that ICAO has responded.

ICAO tasked a team of global experts to develop the multi-crew pilots licence (MPL). Work began in 2000 when the industry was relatively slack. Contrary to popular comment, MPL was not designed for time or cost savings: the driver was relevance and quality. ICAO MPL Doc 9868 was eventually published in 2006. A broad understanding of MPL in 2010 does not exist. Some comments on MPL follow:

- **Hours of real flight time:** In simple terms of hours flown, the new MPL program prescribes minimum exposure for students to approximately 33% of traditional time in air. From this fact alone it is easy to dismiss MPL without delving deeper. But flying hours are no agent of effective learning without structured relevance and quality instruction.

The total MPL training time in aircraft and simulators does exceed traditional CPL programs. Simulation more than compensates for reduced flight hours and every hour of instruction is relevant to eventual airline operations.

Beta trials have also shown how the aircraft flight training phase can be enhanced by running the aircraft training exercise three times: (a) in the related type simulator, (b) in the aircraft, and (c) via video debrief.

- **Holistic integrated program:** The MPL footprint is integrated holistic training, ruthlessly dedicated to the airliner flight deck, not on how to fly light singles, twins, and business jets Nevertheless fundamental skills acquisition in Critical areas must be taught to competency - a training objective of great importance today:
- **Embedded training:** Throughout MPL training crew resource management (CRM), threat and error management (TEM), and ATC communications are ICAO requirements. Although most if not all these training objectives can be found in existing CPL programs, the content is often delivered as stand-alone (box ticked) module, rather than a platform that remains continuously embedded in the syllabus.
- **Competencies:** The concept of acheiving defined competencies at every gate during the progam is educationally well understood, but forms a significant challenge in flight training. However, much recent work on task analysis and instructiorlal design is providing best practice templates for MPL.
- **MPL Training aircraft:** Modern training aircraft applied to MPL have many airline-

typical features by design, such as FADEC, EFIS, typed simulators, and cockpit observation seats. Two students can observe air exercises, and many more ground simulation.

- **MPL Simulation:** Revised flight simulation training device (FSTD) categories will be published soon by ICAO as an update to Doc 9625. This expanded listing (1 -V11) results from an exhaustive program of R&D conducted by the Royal Aeronautical Society, which matched equipment to training objectives. Augmenting the standard Level D FSTD, ATC simulation (Using voice recognition system tells), is also a requirement of MPL. As experienced airline pilots know well, the challenge of accurate voice communications remains a serious safety system deficiency despite the growing application of non-voice communication, and enforcement of ICAO English standards at Level 4 and above.
- **Continuous enhancements:** In the last analysis the ICAO MPL is only a best practice training framework, and it is up to responsible training organisations to put appropriate "fat on the bone" But if this "fat" is not fully aligned with the MPL concept, negative training and wasted program time may result.

For example, some training organisations and regulators have added the same traditional light-twin and jet performance training to the MPL framework often found in traditional CPL training, possibly to provide a perceived sense of security with new program introduction, and to utilise assets which already exist. Performed in additional non-airline aircraft, the MPL concept is impaired, and the student may lose focus. Unnecessary cost is also added to the program.

An example of more appropriate fat on the bone is the current focus on recovery from unusual attitude (UA) training, which is a base requirement of MPL. In response to increasing dominance of loss of control (LOC) incidents, the industry is vigorously researching more effective ways to apply this training, which must become a high impact component of MPL, both in aircraft and simulators.

Suffered

MPL requires attitude change and has suffered from some poor publicity in early inception. Some training organisations have marketed their new MPL program as "cheaper and faster" This objective was never included in the brief for the six-year ICAO development team.

A freshly qualified general aviation pilot with an instructors rating may have been initially acceptable for the CPL program decades ago, but for airline operations is not today. Many were only instructing to build their hours for eventual airline employment, a distracting objective, and most had no practical airline experience. New MPL instructor courses are emerging in recognition of the need to lift the bar of instruction to airline-relevant level. At the very least, the instructor at the start of the student's first MPL exercise must have a clear understanding of the ultimate purpose of the training: the airline pilot's task.

MPL has already demonstrated competent graduates in base training. The first Alteon trial of 6 Chinese pilots generated positive reports from the flight inspectors who observed the base training on B737NGs in China. Competency was achieved in six to 12 landings with pilots who had a fraction of traditional aircraft flight time, and for whose experience level the CAAC would have required 30 landings.

Many organisations are now training or operating the MPL program and over 30 states have embodied MPL in their aviation legislation. Comments from IATA suggest that this license will eventually become the only route for cadets to enter airline operations.

In practice, there are signs that MPL may indeed become a slightly less expensive and shorter full process abinitio-to-type rating training program.

Also emerging is the unintended consequence of reduced aircraft fiight time in terms of less exposure to program, and graduation delays caused by poor weather and high density ATC activity. Although this was never the objective of the development team it promises to be a significant advantage in some flight training locations such as China.

Once type rated the new airiine pilot puts the lessons learnt into practice, but not all these lessons will be well remembered in the many years of operational service ahead. So recurrent training programs must evolve to match the relevance of the MPL to provide added reinforcement and safety assurance. The traditional box-ticking approach requiring frequent repetition of low probability failures must give way to the more broadly based recurrent training driven by topical need, as already practiced by some operators.

MPL is leading the way towards the more appropriately trained airline pilot, and forms the basis for future recurrent training modules. The basic concepts of MPL are well understood by the experienced airline instructor, who has been delivering "work-around add-ons" for many years trying to strengthen the relevance of poorly prescribed recurrent training. While MPL sows better seeds, a follow-on process in recurrent training is essential to sustain the required knowledge skills and attitudes.

In parallel with new training inititives, the raw material entering the commercial aviation system must be further optimised in selection to ensure that future pilots are the motivated "right stuff" necessary for future safety levels.

A worthy objective, well recognised by training professionals, is to drive training programs from safety data. This is now becoming possible as technology matures. Anticipating this, training programs should not be set in stone but be redesigned to be malieable. While founded on a sound footprint built around task analysis, performance-measurement and competency standards, programs should also be designed to accommodate continuous change.

More radical action is needed to drive the training process to a higher level and reduce human error in the airline system or we will probably see more unpleasant safety outcomes.

About the Author

John Bent has been actively engaged in aviation training via a 45 year piloting career spanning the RAF, GA, and 4 airlines, and is currently leveraging his experience to help establish (with the Asia Development Assistance Board) a new MPL-based training academy in China, geared to the highest contemporary standards realistically attainable.

Reprinted with acknowledgement to CAT Magazine.

Staying Sharp With Age

By Patrick R. Veillette, Ph.D.

CHANGES AMONG SENIOR PILOTS' MENTAL ATTRIBUTES CAN BE MANAGED AND SO THEIR EXPERTISE ENDURES.

A little gray at the pilot's temples has long been valued by operators and passengers alike, since it signaled long experience. But with the general economic meltdown of 2008 that saw 401K plans halved and pensions disappear, the gray will become total as many business aviation pilots who had planned on retirement in the next five years remain in the cockpit for quite a bit longer.

The community will benefit from that long and ever more valuable piloting experience. But the downside is an increasingly aging pilot population that, statistically speaking, will suffer deterioration in sensory, perceptual and cognitive properties, along with motor skills, alertness and endurance that are all important to piloting excellence.

Researchers from Johns Hopkins University examined accident records to determine if accident patterns changed according to the ages of the pilots involved. The authors followed 3,306 commuter air carrier and air taxi pilots who were aged 45 to 54 years in 1987. During the following 10 years, those pilots accumulated a total of 12.9 million flight hours, during which 66 of the pilots experienced aviation crashes, yielding a rate of 5.1 crashes per million pilot flight hours. The authors found that the accident risk remained fairly stable as the pilots aged from their late forties to their late fifties. They also found that flight experience, as measured by total flight time, showed a significant protective effect against the risk of accident involvement. Pilots who had 5,000 to 9,999 hours of total flight time had a 57-percent lower risk of an accident than their less-experienced counterparts. The positive effect of flight experience leveled off after total flight time reached 10,000 hours.

So does experience offset or forestall some of the negative effects of aging? To a certain extent, yes ... and no. Researchers from the Department of Veterans Affairs and the Stanford University School of Medicine found that expert knowledge may compensate for some age-related declines in basic cognitive and sensory-motor abilities. (Cognition is the important mental process of knowing, including aspects such as awareness, perception, reasoning and judgment.) They studied 118 pilots aged 40 and 69 over a three-year period on items such as executing airtraffic controller communications, traffic avoidance, scanning cockpit instruments, and executing an approach to landing. Pilots with the most experience had better flight summary scores at the beginning of the experiment and also showed less decline over time. The study found a definite advantage of prior experience and specialized expertise on older pilots' skilled cognitive performances.

One of the most common symptoms as we grow older is the apparent increase in memory lapses, a symptom that is not offset by experience. The aviation environment demands recall and places a premium on memory resources. We're all forgetful on occasion; however, with increasing age, forgetfulness becomes more frequent. The University of Michigan Health System's *Memory and Aging* tells us that after age 20, humans begin to lose brain cells and our bodies begin to manufacture less of the chemicals needed for the brain cells to function.

Short-term memory is the information we remember temporarily, often for less than a minute and then it is easily replaced by new information. During inflight operations our short-term memory serves to recall a plethora of rapid-fire directives, including often-complicated taxi clearances, new altitudes and radio frequencies, and sometimes even more in a single amended clearance.

And pilots are susceptible to declines in this important ability. "Aging, Expertise and Narrative Processing," a 1992 study, found that pilots exhibit age-related declines in the recall of aviation-related materials even

though the older pilots had significantly more experience. "When Expertise Reduces Age Differences in Performance," another study by the same authors, found that older pilots showed more errors in the recall of ATC clearances.

Other leading memory problems in the aging person include a decline in memory storage, requiring more time to learn new information, and the inability to pay attention to several things simultaneously. Obviously, these problems impact good piloting. There are yet other aspects of memory loss that have a negative effect on pilot performance. One is transience, which is forgetting information with the passage of time, and then, too, there's absent-mindedness. Have you ever felt the correct information is "on the tip of my tongue" but still unavailable? This is termed "blocking" and is another aspect of memory that deteriorates with aging. Some of the other maladies include developing a false memory, which is the unconscious reshaping of a memory because of personal beliefs or mood, and negative distortions of the memories of a traumatic event.

There are some steps a senior pilot can take to prevent memory loss. While genetics partially governs our ability to remember, there are lifestyle changes that can help slow down this aging effect. In its "Improving Memory: Understanding and Preventing Age-Related Memory Loss," the Harvard Medical School found that leading a healthy lifestyle including physical health, minimal emotional stress, limited consumption of alcohol, a healthy diet, abstinence from smoking, and at least six hours of quality of sleep each night could act synergistically to help reduce memory loss. Physical activity can also reduce memory loss by increasing , the flow of blood to the brain and promoting the growth of new brain cells. A minimum of 30 minutes of exercise on most days is recommended. A healthy low-fat diet, including fruits and vegetables that contain antioxidants and fish and other foods that contain omega-3 fats may help nourish brain cells as well as limit the buildup of cholesterol in the arteries.

Age-related memory loss, can also be checked somewhat by engaging in activities that, challenge the mind. When learning continues, the brain forms new connections between nerve cells. This helps the brain store information and retrieve information, regardless of age. The Mayo Clinic's "How to Keep Your Mind Sharp: Prevention Action" has an extensive list of such activities. Mental challenges include learning to play a musical instrument, learning a foreign language, changing careers, developing a new hobby, volunteering, staying informed about world events, reading and interacting with other people.

The ability to learn new operating procedures, new aircraft systems and such definitely becomes more difficult as a pilot ages. Recent research on learning has found that older people tend to rely on their previous knowledge, and don't retain newly learned material in long-term memory as well. Thus when pilots set out to learn something new such as a different FMS, they'll rely on the skills and general knowledge acquired over a longer period of time. These studies have shown that older participants (60 to 70) were slower and made more errors than younger pilots, especially on tasks requiring more information processing. One possible cause may lie in changes in cognitive processing associated with increasing age.

"Age-Related Group and Individual Differences in Aircraft Pilot Cognition," a joint study between Loyola Marymount University and UCLA's Department of Psychiatry and Biobehavioral Sciences observed significant age-related differences in tests of psychomotor skills (mental events that have motor consequences or vice versa), information processing speed, attention, executive ability, verbal and visual learning, and memory. The study confirms the findings of other research on pilot cognition and aging.

This decline in a person's cognition ears to be gradual across the age range. There was no appreciable acceleration of cognitive loss with pilot age. Rather, a linear decline best describes pilot cognition differences between ages 28 and 62. While scientific protocol prevented authors from extrapolating effects to pilots more senior, they did opine it is possible that decline in cognition acceles after 62.

Many of the tests in this study required timed performance. The association of slower completion times with older pilots indicates, among other things, a fundamental slowing in psychomotor speed and cognition. Although such slowing may minimally impact pilot performance in routine flight situations, it could be a more significant factor in non-routine or emergency flight situations that demand mpt pilot analysis and decision making.

The association of slower completion times with older pilots indicates, among other things, a fundamental slowing in psychomotor speed and cognition.

One contributing factor to the cognitive slowing observed in older pilots is cardiovascular status. In a study of 671 men, most of whom had been pilots or air traffic controllers or both, mild to moderate degrees of cardiovascular disease were associated with slower psychomotor performance. Much of the typical downward trend in performance with age is a reflection of cardiovascular diseases rather than age, per se. While cardavascular-related incapacitation of a pilot resulting in an accident is rare, the vascular condition presumably has a common and subtle impact on pilot cognitive functioning. And a growing body of evidence suggests that "cardio" excercise can at least partially mitigate age-related slowing across a variety of psychological and physiological measures and thus could potentially reduce the risk of older pilots in demanding, quick-response, inflight situations.

Fatigue is another important issue regarding the performance and safety of the aging pilot. Mark Rosekind, former principal investigator of human fatigue at the NASA Ames Research Center, along with co-author Linda Connell, the director of the NASA ASRS system, found that with normal aging, nighttime sleep becomes shorter, lighter and more disturbed with more awakenings and transient arousals, and daytime sleepiness increases. Among crewmembers in the study of long-haul operations, pilots aged 50 to 60 averaged 3.5 times more sleep loss per day than those aged 20 to 30. This correlated well with laboratory studies that indicate greater variability among older persons in sleep and circadian rhythms. The NASA results, published in the aeromedical journal *Aviation Space and Environmental Medicine*, noted that sleep loss of as little as one hour per night causes a cumulative increase in physiological sleepiness during the day. Furthermore, the magnitude of the sleep loss accumulated over successive duty days can be sigmficant.

Rosekind and Connell concluded that countermeasures for circadian disruption and sleep loss may need to be adapted for different age groups and/or circadian types.

Individuals do not age physiologically at the same rate, and since variations in cognitive function between individuals increases greatly as age increases it's extremely difficult to predict an individual's functional level. Thus a 62-year-old pilot can be super sharp whereas one 18 years his junior may never be. This variation made it extremely difficult for aeromedical researchers to argue for or against mandatory retirement ages. Some individuals, because of genetics, health, exercise, diet and such, will continue to remain relatively sharp for their age group, whereas others were never that sharp in the first place or will decline at a more rapid rate. As to the question of when these aspects of aging begin to degrade cockpit performance enough to constitute a threat to flight operations, the normal aeromedical certification provides no answer. Dr. Anthony Evans, chief of ICAO's Aviation Medicine Section, opines, "As we don't have adequate assessment tools to accurately determine who is in one group or another, a one-size-fits-all approach, based on average risk, is the fairest system. Without a retirement age, the logical conclusion is that pilots will operate until they fail a medical or an operational check. Without a cultural change, there will continue to be a reluctance (by medical examiners and check pilots) to fail an experienced pilot, with his career (perhaps a glittering one) ending in failure." He noted that, "Medical evaluations and simulator checks developed to determine whether pilots have age-related problems would help identify those who are no longer fit for flight, but are far from being 100-percent accurate."

I watched a colleague go through a cognitive evaluation after being accused of exhibiting signs of "cognitive decline" and can attest that it is not a process anyone would welcome to maintain flying privileges. Before undergoing such an evaluation, consult an aeromedical advisor to assist in your preparation since one's pilot certificate could be riding on the results. There are some online and in-clinic preparatory courses available to help individuals prepare, with the online courses requiring self-discipline.

One of the attributes that the cognitive psychologists will examine in making such an assessment is the subject's attention skills including concentration, patience and restrained compulsivity. Some of the common tests will require the pilot to learn a new sequence of letters on a computer, scan to find the correct letter and use working memory to store a letter's location. This allows clicking the letter to shift attention quickly and move the mouse and click on the next letter. The individual's speed and accuracy are both graded. The tests may also examine visuospatial skills by discerning line widths, angles and completion of line drawing. Others skills to be tested will be eye-hand coordination, deductive and inductive logic, memory and communication.

Unfortunately in the evaluation of my colleague two different psychologists came up with contrary diagnoses. Because the industry hasn't come up with a defined limit of what is acceptable performance vs. unacceptable, the aviation manager is left to decide if it is time to remove the pilot from the roster.

The issue of pilot aging is a tough one for managers to handle, since they must weigh expertise and loyalty against slowed reaction and comprehension. By staying alert to those changes and proactive in crew pairing a superior level of safety can be maintained. There inevitably does come a time when a pilot should exit the cockpit for good, but the right time depends on the individual, not the calendar.

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