29th Congress of the International Council
of the Aeronautical Sciences
St. Petersburg, Russia; September 7-12, 2014

DEVELOPMENTS IN ACCIDENT PREVENTION

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Keywords: *SMS; Accident Prevention; Flight Recorders; ULB*

Abstract

This study examines recent developments in accident prevention which have led to the reduction in accident rates for commercial aircraft operations. Accident data is analysed to identify the strategies and innovations which have resulted in the prevention of accidents. Case studies from the Asia Pacific region are used to illustrate some of these advances in accident prevention. Further strategies are suggested to maintain safety levels and for further improvements in aviation safety.

1 Introduction

Unlike the previous two years, the worldwide commercial jet accident rate did not achieve a record low point in 2013, but it was still an excellent year for aviation safety. Statistics indicated that there was roughly one passenger death for every 7.1 million air travellers worldwide.

Improvements in accident statistics do not guarantee increasing safety and there were many high risk events which could have had bad outcomes and would have significantly changed these trends.

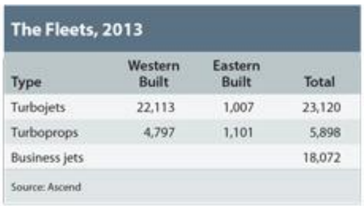
While the year's records are noteworthy, they don't guarantee future safety and could even undermine it by breeding complacency.

2 Current Safety Statistics

The Flight Safety Foundation [1] annual review of safety statistics shows that the 2013 commercial jet major accident rate was 0.24 accidents per million departures, which is an increase from 2012’s record rate of 0.14, but below 2011’s rate of 0.28. The 2013 rate is the second-lowest rate ever recorded. There were two commercial jet “upset” aircraft accidents in 2013, the first in two years, and controlled flight into terrain (CFIT) accidents continued the trend from previous years. Four of the seven commercial major jet accidents were CFIT accidents.

The data for commercial turboprops also shows a slight increase from their 2012 low point in terms of number of accidents for the year. CFIT accidents again dominated the turboprop fatality numbers. Business jets had eight major accidents in 2013, an improvement from the 2012 total of 13. Table 2 shows the major accidents that occurred in 2013 for all scheduled and unscheduled passenger and cargo operations for Western-built and Eastern-built commercial jet aircraft. Five of the seven accidents happened during the approach and landing phase of flight. As mentioned, four of the seven were CFIT accidents, and there were two jet “upset” aircraft accidents.

Figure 1 shows the total number of commercial jet major accidents and the number of Eastern-built aircraft accidents for commercial jets since 2002. Over the last five years, an average of 5 percent of the active commercial jet fleet was Eastern built, but they accounted for 30 percent of the major accidents over that same period.



The Fleets, 2013

Type	Western Built	Eastern Built	Total
Turbojets	22,113	1,007	23,120
Turboprops	4,797	1,101	5,898
Business jets			18,072

Source: Ascend

Table 1

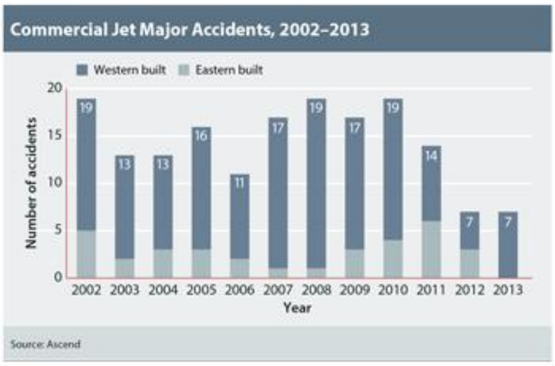
Major Accidents, Worldwide Commercial Jets, 2013

Date	Operator	Aircraft	Location	Phase	Fatal	
Jan. 29	SCAT Air	CRJ-200	Almaty, Kazakhstan	Approach	21	🔵
April 13	Lion Air	B-737	Bali, Indonesia	Approach	0	🔵
April 29	National Airlines	B-747	Bagram, Afghanistan	Takeoff	7	🔴
July 6	Asiana Airlines	B-777	San Francisco	Landing	3	🔵
Aug. 14	UPS	A300	Birmingham, Alabama, U.S.	Approach	2	🔵
Nov. 17	Tatarstan Airlines	B-737	Kazan, Russia	Approach	50	🔴
Nov. 29	LAM	EMB-190	Bwabwata Park, Namibia	En route	33	

🔵 Controlled flight into terrain 🔴 Loss of control–in flight (upset aircraft)

Source: Ascend

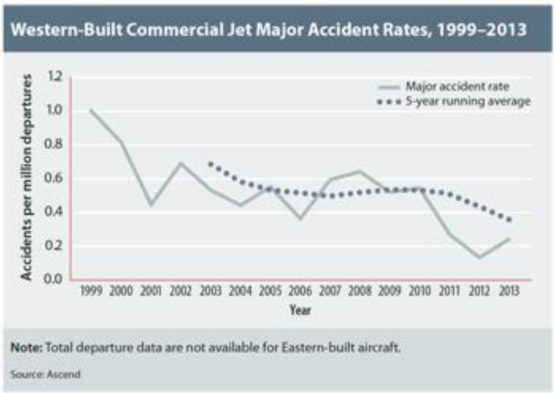
Table 2



Commercial Jet Major Accidents, 2002–2013

Source: Ascend

Figure 1



Western-Built Commercial Jet Major Accident Rates, 1999–2013

Note: Total departure data are not available for Eastern-built aircraft.

Source: Ascend

Figure 2

There were no Eastern-built commercial jet major accidents in 2013. Figure 2 shows the commercial jet major accident rates and the five-year running average. This rate is only for Western-built jets because, even though we know the number of major accidents for Eastern-built jets, we do not have reliable worldwide exposure data (hours flown or departures) to calculate valid accident rates. After a decade of negligible improvement in the accident rate for commercial jets, a very positive trend of improvement that started in 2011 is evident, and the five-year running average continues to decrease.

The accident rate for business jets can be calculated as the number of major accidents per 1,000 aircraft. Figure 3 uses this metric, and it shows an improvement in the business jet accident rate over the last nine years. Figure 4 shows the number of turboprop accidents since 2002. CFIT accidents continue to dominate the accident and fatality numbers for commercial turboprops. In 2013, eight of the 22 major accidents were CFIT accidents. Over the last seven years, 30 percent of the commercial turboprop major accidents have been CFIT accidents.

3 Accident Categories

CFIT, approach and landing, and "Upset" aircraft accidents continue to account for the majority of accidents and cause the majority of fatalities in commercial aviation. Of the seven commercial jet major accidents in 2013, five were approach and landing accidents. Over the last five years, 70 percent of commercial jet major accidents have been approach and landing accidents.

Figure 5 shows the CFIT accidents for all commercial jets since 1999. The upward trend since 2009 is quite disappointing because more than 95 percent of all commercial jets have been equipped with TAWS (terrain awareness and warning systems) since 2007. Over the previous six years, there have been 38 commercial aircraft CFIT accidents (14 turbojet, 24 turboprop). Only three of these 38 aircraft were equipped with operating TAWS. In those three aircraft, the TAWS provided 30 seconds or more of warning of the impending collision with the ground.

In the last two years, over 50 percent of the commercial jet fatalities have been caused by CFIT accidents.

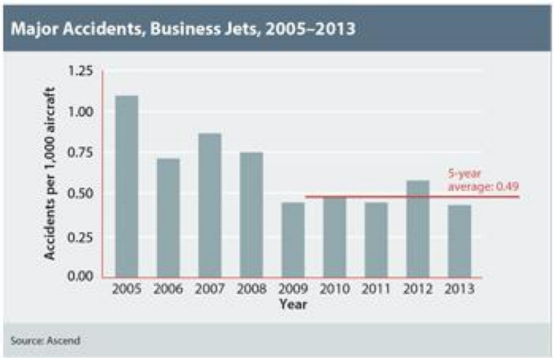


Figure 3

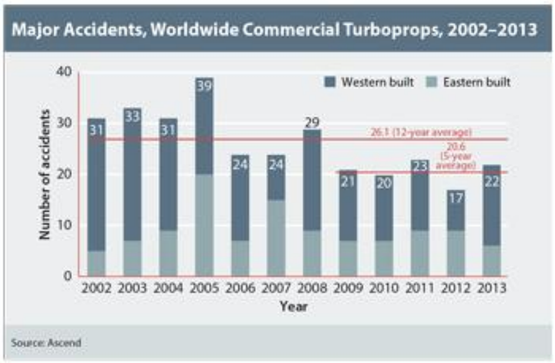


Figure 4

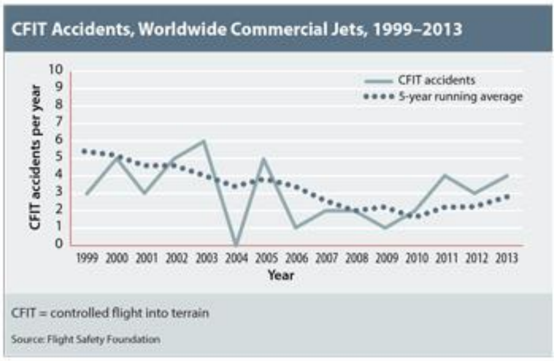


Figure 5

Over the last three years, commercial jets have suffered 11 CFIT accidents and two upset aircraft accidents. Because of this, and the number of CFIT accidents involving turboprop aircraft, CFIT is again a major concern.

While CFIT accident prevention is an area for improvements, there have been significant developments in preventing "Upset" aircraft accidents which were the highest rate of fatal accidents, due to their inherent characteristics. There were no upset aircraft accidents in the previous two years. Airlines had two cases in 2013. There are numerous international efforts under way to reduce the risk of upset aircraft accidents, and the recent decrease in upset accidents indicates these efforts may be having some success.

4 Accident Prevention

The 1970-1980 era was the advent of technological advances which improved aircraft reliability and introduced many safety devices which reduced aircraft accidents. The technological advances continued through the 1980-1990 period which was also characterised by Professor James Reason's work on accident causation. The development of the Reason model is well known and has become a basic tool for investigations. Through this approach further improvements in aviation safety were achieved.

Locals gather at the site of a turbo-prop aircraft accident near Madang in Papua New Guinea that killed 28 passengers. The aircraft went down as a violent storm approached.

Analysis of serious accidents indicates that many established aircraft operators have exhausted the advances offered by the earlier safety management strategies developed in the 1980/2000s and that new ideas are needed. A step change for the better in airline safety performance took place around the year 2000, but those advances have become entrenched. And while safety today is at an all-time high, improvements in the safety rate stopped in the mid-2000s. The plateau marked a departure from a century of aviation safety that had shown a steady improvement since the Wright Brothers.

The latest initiatives are based around Safety Management Systems (SMS). It is expected that the development of the SMS concepts in practice and the worldwide acceptance of their benefits will have significant impact on safety.

5 Safety Management Systems

A Safety Management System is a systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures. From an airline perspective, it is a constituent part of the overall management system of the airline organisation. It is recognised that many organisations are at different levels of the implementation of an effective Safety Management System. Properly administered a safety management system will deliver a company the ability to identify and track potential hazards. Consequently it will permit the hazards to be removed or at least mitigated before any significant damage or injury might be done. That is the theory; in practice the evidence is not so positive.

The key elements of a Safety Management System can be divided into four main components:

- Safety Policy and Objectives
- Safety Risk management
- Safety Assurance
- Safety Promotion

It seems we are bombarded with information about “safety management systems” these days in everything we read in the safety press and publications. The classic SMS includes elements of safety occurrence and hazard reporting and safety investigations. It could be argued that without a good reporting culture, the management of “safety” is almost impossible. If we do not know what is happening on the flightline or in the hangar, then we cannot make the necessary improvements to reduce risk and improve safety levels. Managers and supervisors will be in blissful ignorance of the real situation until a serious event occurs that cannot be ignored. The ideal situation is that any safety hazard or safety concern is reported and action is taken to address these before they become an incident or accident. This is the utopia of preventive or proactive safety. In practice, this is very hard to achieve as operational staff members usually have very little time for non-operational tasks and do not perceive the benefit from reporting something “that might happen.” Changing the mindset is essential if SMS is to be successful. It is also greatly assisted if the reporting process is simple and readily accessible such as being able to submit a safety report during the cruise phase, for example. Electronic reporting is ideal, but the use of paper forms is still widespread and effective. They can be completed after the finish of a flight at home or in the hotel.

Safety assurance is accomplished through flight data monitoring, line operations safety audits, and safety actions from system improvement recommendations. An operator’s SMS is an easy target for the investigators after an accident. Determining why the SMS failed is not so easy. However, it has been reported that many smaller operators have met the letter of the legislation by constructing a SMS manual, in some cases supplied by external consultants. But the elements of SMS have not been rolled out to day-to-day operations. Some of the reasons include cost, and a reluctance to be open with the staff about safety issues.

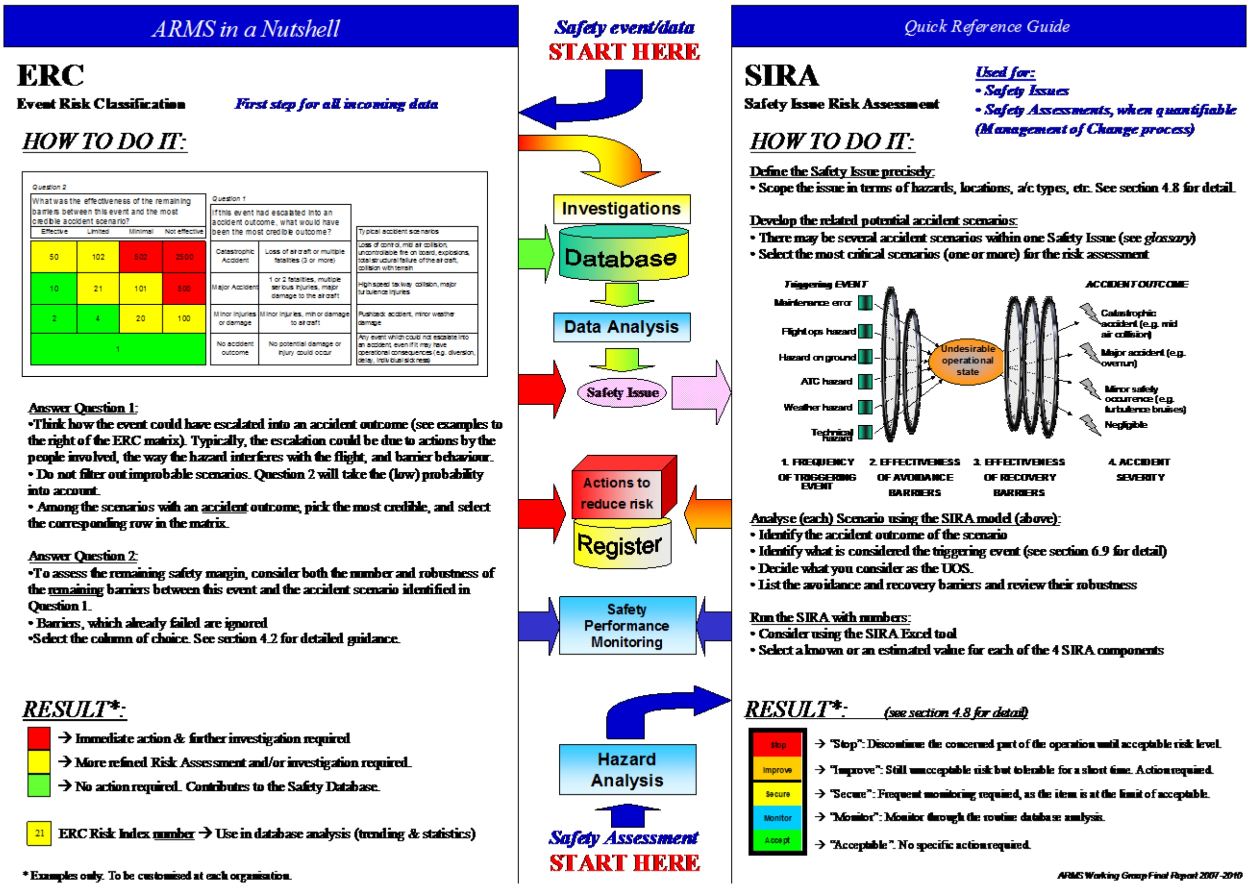
This must change if the promise of SMS in reducing accidents is to occur.

Although all the elements are essential for an effective SMS it can be argued that the Safety Risk Management is the key to an effective SMS. These are the processes that identify hazards and attempt to address the hazards and reduce the risks to the lowest practical level (ALARP). Without knowing what is happening at the frontline management cannot implement an effective SMS to address the operational hazards. Without the key elements of safety occurrence reporting, safety investigations and auditing the Operational Risks will not be managed and the Safety Management System will not be effective.

To be effective all staff must be engaged and understand the Safety Management System. The basic questions which a SMS should answer are: what are the operational risks and what would be the most likely causes, what mitigation strategies have been introduced to reduce the risks and how effective are they?

The International Civil Aviation Organisation (ICAO) has published a framework for a typical Safety Management Systems (SMS) with Risk Management as the core component. ICAO has created a new standard for SMS in various aviation organisations, including among others: airlines, maintenance organisations, ATC services, aerodromes. Risk Assessment has a central role in the Safety Management System. For many reasons, Risk Assessment is a very challenging task. Older methods have been characterised by high levels of subjectivity and other difficulties. A recent initiative is the work of the Airline Risk Management Solutions group. The Airline Risk Management Solutions (ARMS) Working Group worked from 2007 to 2010. [4] It was made up of aviation safety professionals and aimed to produce a useful and cohesive Operational Risk Assessment method for airlines and other aviation organisations. The development of this methodology was supported by the European Commercial Aviation Safety Team (ECAST). ECAST addresses large fixed wing aircraft operations, and aims to further enhance commercial aviation safety in Europe, and for European citizens worldwide. It was launched in October 2006.

The industry working group, ARMS (Aviation Risk Management Solutions) was set up in order to develop a new and better methodology for Operational Risk Assessment (ORA). The primary target group for the methodology is airlines but it will also be fully applicable to other aviation organisations. The working group consisted mainly of safety practitioners from airlines. This was to ensure that the proposed methodology is applicable to the real-life setting of an airline or other aviation organisation. The methodology defines an overall process for Operational Risk Assessment and describes each step. The assessment process starts with Event Risk Classification (ERC), which is the first review of events in terms of urgency and the need for further investigation. This step also attaches a risk value to each event which is necessary for creating safety statistics reflecting risk. The next step is data analysis in order to identify current Safety Issues. These Safety Issues are then risk assessed in detail through the Safety Issue Risk Assessment (SIRA). The whole process ensures that any necessary safety actions are identified and creates a Register for following up risks and actions and provides a Safety Performance Monitoring function. SIRA can also be used to make Safety Assessments, which is a requirement of the “Management of Change” element of the SMS.



ARMS in a Nutshell

ERC

Event Risk Classification

First step for all incoming data

HOW TO DO IT:

Question 2: What was the effectiveness of the remaining barriers between this event and the most credible accident scenario?				Question 1: If this event had escalated into an accident outcome, what would have been the most credible outcome?		
Effective	Limited	Minimal	Not effective			Typical accident scenarios
50	102	502	2500	Catastrophic Accident	Loss of aircraft or multiple fatalities (3 or more)	Loss of control, mid air collision, uncontrollable fire on board, explosions, total structural failure of the aircraft, collision with terrain
10	21	101	500	Major Accident	1 or 2 fatalities, multiple serious injuries, major damage to the aircraft	High speed taxiway collision, major turbulence injuries
2	4	20	100	Minor injuries or damage	Minor injuries, minor damage to aircraft	Pushback accident, minor weather damage
1				No accident outcome	No potential damage or injury could occur	Any event which could not escalate into an accident, even if it may have operational consequences (e.g. diversion, delay, individual sickness)

Answer Question 1:
•Think how the event could have escalated into an accident outcome (see examples to the right of the ERC matrix). Typically, the escalation could be due to actions by the people involved, the way the hazard interferes with the flight, and barrier behaviour.
• Do not filter out improbable scenarios. Question 2 will take the (low) probability into account.
• Among the scenarios with an accident outcome, pick the most credible, and select the corresponding row in the matrix.

Answer Question 2:
•To assess the remaining safety margin, consider both the number and robustness of the remaining barriers between this event and the accident scenario identified in Question 1.
• Barriers, which already failed are ignored
•Select the column of choice. See section 4.2 for detailed guidance.

RESULT*:

🟥 → **Immediate action & further investigation required**
🟨 → **More refined Risk Assessment and/or investigation required.**
🟩 → **No action required. Contributes to the Safety Database.**

21 **ERC Risk Index number → Use in database analysis (trending & statistics)**

*** Examples only. To be customised at each organisation.**

Quick Reference Guide

SIRA

Safety Issue Risk Assessment

Used for:
• Safety Issues
• Safety Assessments, when quantifiable (Management of Change process)

HOW TO DO IT:

Define the Safety Issue precisely:
• Scope the issue in terms of hazards, locations, a/c types, etc. See section 4.8 for detail.

Develop the related potential accident scenarios:
• There may be several accident scenarios within one Safety Issue (see *glossary*)
• Select the most critical scenarios (one or more) for the risk assessment

Analyse (each) Scenario using the SIRA model (above):
• Identify the accident outcome of the scenario
• Identify what is considered the triggering event (see section 6.9 for detail)
• Decide what you consider as the UOS.
• List the avoidance and recovery barriers and review their robustness

Run the SIRA with numbers:
• Consider using the SIRA Excel tool
• Select a known or an estimated value for each of the 4 SIRA components

RESULT*: ***(see section 4.8 for detail)***

Stop → **"Stop": Discontinue the concerned part of the operation until acceptable risk level.**
Improve → **"Improve": Still unacceptable risk but tolerable for a short time. Action required.**
Secure → **"Secure": Frequent monitoring required, as the item is at the limit of acceptable.**
Monitor → **"Monitor": Monitor through the routine database analysis.**
Accept → **"Acceptable". No specific action required.**

ARMS Working Group Final Report 2007-2010

ECAST is a partnership between European Aviation Safety Agency (EASA), other European regulators and the aviation industry. ECAST is based on the principle that industry can complement regulatory action by voluntary committing to cost effective safety enhancements. Most aviation organisations are required by their National Aviation Authority to implement a Safety Management System (SMS). The ARMS method is intended not only for airlines and other air operators, but also for other aviation organisations like MRO's, Air Traffic Control organisations and Aerodromes. In addition to giving the solution for Risk Assessment, the ARMS Methodology is expected to foster increased cooperation between organisations using ARMS. Customising the Methodology to the specific needs of an organisation is addressed in the ARMS documentation.

6 Technology Advances

Significant improvements in aviation safety through accident prevention have been achieved by utilising technological advances. Both Boeing and Airbus for example have introduced many innovations in their latest products. The advent of the "digital" aircraft has been the catalyst for significant accident prevention strategies. But there are still several areas where improvements can be made to enhance accident prevention. Runway excursions and runway overruns are still the most frequent accident types [2].

While most runway excursions are relatively minor with no serious injuries or no aircraft damage occurring, they do have the potential to pose a serious risk to public safety and infrastructure. This has been illustrated by several significant runway overruns around the world in the last 10 years resulting in hundreds of on-board fatalities, as well as ground fatalities and significant property damage in communities adjacent to airports.

Preventative risk controls are the most important way to reduce the likelihood and consequences of runway excursions. These include reinforcement of safe approach techniques, pre-landing risk assessments, line-oriented flight training, clear policies on go-arounds, quality runway surfaces with safety features such as grooving and surface texturing, runway lighting, and indicators of remaining runway length through distance remaining signs and cockpit alert systems.

If these preventative risk controls fail, recovery risk controls are important to mitigate severe consequences if a runway excursion does occur. Recovery risk controls include runway strips, runway end safety areas, soft ground arrestor beds, and public safety areas. A survey of 43 major airports found that runway end safety areas in Australia meet or will soon meet Civil Aviation Safety Authority requirements. A large majority of Australian airports had good quality runway surfaces that reduced the risk of a runway excursion occurring in the first place.

An example of a runway excursion due to weather occurred on 23 January 2014. [3] The ATSB investigation report states:

The pilot of a Fairchild SA226 aircraft conducted a charter flight from Thangool to Archerfield, Queensland, with 11 passengers on board.

The pilot commenced a non-directional beacon (NDB) approach to Archerfield. Approaching the western boundary of the aerodrome, the pilot sighted the runway and circled the aerodrome at 900 ft above ground level (AGL) before approaching to land on runway 10 Left.

Due to the low cloud in the area, the pilot kept the aircraft close to the runway to ensure the runway remained in sight. When lined up on final, the aircraft was to the right of the extended runway centreline and the pilot elected to conduct a go-around.

The second circle was still tight, due to low cloud to the west of the runway, and the pilot reported that the aircraft was about 30 to 50 m right of the extended runway centreline when on final approach. It was raining heavily as the aircraft touched down close to the runway centreline and about 300 m beyond the runway threshold. The pilot reported that as the wheels touched down, the aircraft commenced sliding towards the right, possibly due to aquaplaning. He reduced the power levers to the ground idle setting. The aircraft veered off the right side of the runway and onto the grass. The pilot then attempted to steer the aircraft back onto the sealed surface and momentarily increased the power on the right engine to assist in regaining control of the aircraft. The aircraft then slid along the runway and veered off to the left side. As the left main landing gear entered the grass, the aircraft slowed, coming to rest at an angle of about 30 degrees to the runway and with the main landing gear on the grass.

A runway inspection revealed standing water up to 50 mm deep on the right side of the runway near the threshold. After the incident, aquaplaning marks were visible on the runway.

This is a good example of a relative safe outcome due to the runway design and lack of obstacles. With 12 POB this could have had much worse consequences and would have been a very serious accident by Australasian standards.

7 Human Performance

Human Performance, whether it be on the flight-deck, in the aircraft cabin, in the maintenance hangar or in the Air Traffic Control Tower, has been a major area for accident prevention through the work of people such as Professor James Reason, and Professor Patrick Hudson. Concepts have been developed and enhanced such as Crew Resource Management and Safety Management Systems through a deeper understanding of human performance and its limitations.

A review of accident data shows that human performance issues were often cited as the "cause "of accidents. Through education and training this aspect has been reduced so that accidents involving human performance deficiencies have been greatly reduced in number. And recent serious occurrences have demonstrated how training has prevented catastrophic accidents.

8 Australasian Human Factors Examples

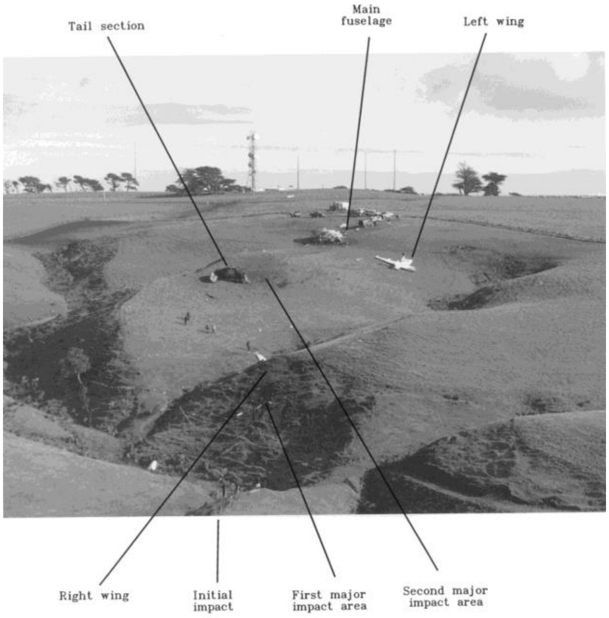
As an example of the development of human factors such as CRM, there was a fatal accident involving a RPT De Havilland Dash8 in New Zealand in 1995. This was one of the worst accidents in New Zealand and was mainly attributed to human factors. Fifteen years later there were "incidents: involving Dash8 aircraft which had similar causal factors but both these later events were handled safely and accidents were avoided.

The Transport Accident Investigation Commission Report of the fatal 1995 accident summarised the results of the investigation [5]:

At approximately 0922 hours on Friday 9 June 1995 a de Havilland DHC-8 aircraft, ZK-NEY, collided with the terrain some 16 km east of Palmerston North Aerodrome while carrying out an instrument approach. One crew member and three passengers lost their lives and two crew members and 12 passengers were seriously injured in the accident.

The causal factors were: the Captain not ensuring the aircraft intercepted and maintained the approach profile during the conduct of the non-precision instrument approach, the Captains perseverance with his decision to get the undercarriage lowered without discontinuing the instrument approach, the Captain's distraction from the primary task of flying the aircraft safely during the First Officer's endeavours to correct an undercarriage malfunction, the First Officer not executing a Quick Reference Handbook procedure in the correct sequence, and the shortness of the ground proximity warning system warning.

Cockpit section ZK-NEY



Accident Site - General View

This was a classic CFIT accident.

Amongst the causal factors was the Captain's distraction from the primary task of flying the aircraft safely during the First Officer's endeavours to correct an undercarriage malfunction. Safety issues included the need for pilots to continue to monitor the safe conduct of the flight while dealing with any non-normal system operation.

As is the case in most accident investigations there were many issues identified which contributed to this accident. The operational history of the Dash 8 involved instances of a failure of a main undercarriage leg to extend, or a significant delay in its extension, after the undercarriage had been selected down.

De Havilland Canada, the aircraft manufacturer, and Dowty Canada, the manufacturer of the undercarriage, had addressed the matter in Service Bulletins and had introduced various modifications over a period of years as a means of overcoming the problems encountered. An Airworthiness Directive (CF-89-03) had been issued by Transport Canada in relation to the matter.

Periodic inspections of the undercarriage uplock, including the latch detent area, were carried out in accordance with the aircraft Manufacturers Maintenance Programme. Technical Instructions to engineering staff included inspection of the latch for indentation. However the investigation found that the tests carried out by the undercarriage manufacturer indicated that, at the time of the accident to ZK-NEY, wear on the uplock latch surface was sufficient to have prevented the right undercarriage lowering when the “DOWN‟ selection was made.

The undercarriage “hang-up‟ on the accident flight introduced an abnormal situation which had to be resolved prior to landing. This in turn resulted in the attention of the pilots being diverted from the routine procedures and from the conduct of the approach being flown.

The safety issues discussed in the report are: the need for pilots to continue to monitor the safe conduct of the flight while dealing with any non-normal system operation, the desirability of the Captain assuming manipulative control of the aircraft in the event of an abnormal situation arising, the efficacy of the operator's follow-up on their decision not to modify the aircraft's undercarriage, the efficacy of the operator's flight safety *programme, the design of the Quick Reference Handbook checklists, the limitations of the knowledge-based crew resource management training, the Civil Aviation Authority's shortage of audit staff available to detect weaknesses in operating procedures during its audits, the standard of performance of the aircraft's ground proximity warning system, the completeness of the advice to passengers on the safety equipment carried in an aircraft and the implementation of a minimum safe altitude warning system for the Air Traffic Control radar.*

The lessons from this accident have been significant. There have been two similar occurrences in New Zealand, both of which resulted in successful landings with minor aircraft damage and no injuries.

The first of these occurrences was on 30 September 2010 when a Bombardier DHC-8-311 aeroplane (also referred to as a Dash 8) departed from Wellington International Airport on a scheduled flight to Nelson Aerodrome. The aeroplane diverted to Woodbourne Aerodrome (Blenheim) because of poor weather at Nelson. There were 2 pilots, one flight attendant and 43 passengers on board.

The TAIC reported [6] that *when the pilots moved the landing gear selector lever to DOWN, the left and right main landing gear legs extended normally. The nose landing gear stopped before it had fully extended, probably because debris within the hydraulic fluid blocked a small orifice in the hydraulic ram (actuator) that extended and retracted the nose landing gear.*

The primary system that indicated the status of the landing gear showed the pilots that the landing gear was "unsafe", that the nose landing gear was not down and locked, and that the nose landing gear forward doors were open.

This situation was similar to that in the 1995 accident but the critical issue was how the crew handled the abnormality in a safe manner. The operator had a well-developed CRM program.

The definition of CRM has changed as the theory and practice have evolved, but in an aviation context it is essentially "the effective use of all resources to achieve safe and efficient flight operations" (International Civil Aviation Organization, 1989, p.4). The resources contemplated being used include equipment, all of its features and the procedures that optimise its use; and people, whether on board as crew or not, and particularly their knowledge and ability to assist with problem-solving. In addition, the time available to resolve a problem or abnormal condition can be a useful resource.

The pilots began working through a checklist to troubleshoot the problem. The checklist directed them to an independent verification system designed to show whether the individual landing gear legs were locked down. That system showed the pilots 3 green lights, which verified that all the landing gear was down and locked, in spite of the other indications that the nose landing gear was not.

The pilots assumed that there was a fault in one of the landing gear sensors and continued the approach to land at

Woodbourne in the expectation that all of the landing gear was locked down. On the final approach the landing gear warning horn sounded when the pilots began to configure the aeroplane for landing by selecting the wing flaps to 15 degrees. This warning horn was designed to alert the pilots that the landing gear was not safe. A short time later the ground proximity warning system also alerted the pilots that the landing gear was not locked down. The pilots ignored both of these warnings in the belief that they had been generated from a single sensor that they assumed was faulty and had given them the original unsafe nose landing gear indications.

When the aircraft touched down and the pilot lowered the nose, the nose landing gear was pushed into the wheel well and the aeroplane completed the landing roll skidding on the nose landing gear doors. Damage to the aeroplane was minimal and no-one was injured.

With the nose landing gear stuck in a partially extended position, light from the taxi light was likely detected by the sensor for the down-lock verification system, causing it to give a false green light.

The false green light on the verification system misled the pilots of ZK-NEB into believing that the nose landing gear was fully down and locked.

The verification system for checking if the landing gear is down and locked on the Dash 8 series of aircraft is not reliable enough for pilots to place total trust in it when trying to establish the status of the landing gear.

The second occurrence was similar to this one and to the fatal accident in that it involved unsafe undercarriage indications. However the crew conducted the flight and the abnormal checks in a safe manner so that the aircraft was landed with minor damage.

The TAIC report [7] states that on 9 February 2011 a Bombardier DHC-8-311 aeroplane (known as a "Q300") operated by Air Nelson Limited departed from Hamilton Aerodrome on a scheduled flight to Wellington Aerodrome. On board were 2 pilots, a flight attendant and 41 passengers.

Prior to taking off from Hamilton, the nosewheel steering malfunctioned because an "inhibit switch" in the cockpit was faulty. The faulty switch caused a loss of hydraulic pressure to the nosewheel steering. The nosewheel steering system was considered non-essential, so in accordance with the approved Minimum Equipment List, the aeroplane departed Hamilton with the system inoperative. The trip towards Wellington was uneventful

The nosewheel steering hydraulic power came from the extend side of the landing gear hydraulic system. On the approach to Wellington, none of the landing gear extended when it was selected down. The pilots carried out a go-around to give them time to perform the relevant procedures provided in a Quick Reference Handbook (QRH). The Q300 was fitted with an alternative system for lowering the landing gear when the normal system failed. The "Alternate Gear Extension" procedure succeeded in getting the main landing gear *to extend, but not the nose landing gear, it remained locked in its retracted position.*

There was nothing mechanically wrong with the alternate landing gear extension system. The nose landing gear did not extend because the pilots did not pull hard enough on the handle that should have released the uplock. If the uplock had released, the nose landing gear would have lowered under gravity and locked down.

The pilots decided to divert to Woodbourne Aerodrome and to land with the nose landing gear retracted. No-one was injured in the landing. The damage to the aeroplane was confined to the area around the nose landing gear and the lower forward fuselage.

This is another example of how the lessons from the 1995 fatal accident have been used in CRM programs to ensure priority is given to safe aircraft operation while abnormal checklists and troubleshooting are conducted.

9 Role of Flight Recorders in SMS

As has been demonstrated in many accident investigations, the prompt recovery and analysis of the recorders are essential for the successful outcomes of complex investigations. But many accidents occur over water, and the recovery of the recorders from the seabed becomes a major exercise. The location of the recorders, and in many cases also the location of aircraft wreckage, depends upon the underwater locator device, which emits a sonar signal for 30 days when activated by water. Since the mid-1970s missing or damaged recorders have only prevented a full analysis of the accident in a small number of major accidents. Out of more than 3,000 accidents involving Western-built commercial aircraft, fewer than a dozen CVRs and FDRs have not been found according to the International Air Transport Association. And in most cases enough wreckage was retrieved to piece together a probable scenario, although this could have taken many months and probably did not result in a definitive conclusion of why the accident happened.

Underwater searches [8] were required for an average of one aviation accident per year over the last 30 years. The searches lasted anywhere from 3 days in the case of Alaska Airlines Flight 261, which crashed in the Pacific in January 2000, to 77 days to find the recorders in the Pacific in April 2008.

Alaska Airlines Flight 261 CVR underwater recovery by remote vehicle.

Prompt recovery and analysis of flight recorders are also key elements of Safety Management Systems. Without the information regulatory agencies are not able to take action and any safety improvements may not be effective. The loss of the Air France 447 Airbus A330 over the Atlantic was an example of the difficulties of searching and recovery of the flight recorders. This accident had far reaching consequences for contemporary aviation safety and therefore it was imperative that the flight recorders were recovered. Despite an estimated $40 million spent on the initial two searches a third search had to be conducted to eventually recover the recorders nearly 24 months after the accident.

The investigation of AF447 has taken three years, involving immensely costly mid-Atlantic searches covering 17,000 square kilometres of often uncharted sea bed to depths of 4,700 metres. It was five days before debris and the first bodies were recovered because of the remoteness of the accident site in equatorial waters between Brazil and Africa.

Prior to the recovery of the recorders, the cause of the accident could only be inferred from a few salvaged pieces of wreckage and technical data sent automatically from the aircraft to the airline's maintenance center in France. It appeared to be a failure of the plane's pitot tubes. These had apparently frozen over, giving erroneous airspeed indications and causing the autopilot to disengage. From then on the crew failed to maintain sufficient airspeed, resulting in a stall which lasted for over almost four minutes before the aircraft impacted the sea.

The recent case of Boeing 777 MH370 will be a major step in the development of accident prevention when eventually the aircraft is found. The situation involving a current wide-body aircraft missing without trace for months will prompt significant changes in aircraft tracking and flight- following.

An area of research resulting from the Air France accident is on satellite technology to transmit critical safety information from the aircraft. The idea of sending real-time safety data to a ground station has been around for several years. Certain maintenance data are transmitted now, as it was in the Air France case. However, technology does not currently allow large quantities of data to be transmitted due to bandwidth and cost. When considering that flight recorders have hundreds of parameters recorded each second, to transmit that data to a ground station becomes very problematic. One suggestion is to send basic flight information such as the heading, altitude, speed, and geographical location to a ground station on a regular basis. This is an interesting suggestion as it mirrors the original flight data recording requirements introduced in the 1960s, which stipulated basic five or six parameters. These proved to be too limited for useful accident analysis.

The easier development would be to lengthen the duration of the underwater locator signals on the flight recorders or improve the signal strength so that the recorders can be located quickly and easily in extreme situations. It has been suggested that the specification for the duration of the signal transmission should be increased to 3 months. Other options for satellite tracking such as EPIRBs could be considered.

Despite ongoing studies for the potential for streaming data to a ground station during flight, the traditional onboard flight data recorder will still be the essential tool for air safety investigation. The reasons are the high costs of data streaming and the massive amounts of data currently recorded and often needed to understand the complexity of aircraft systems. A recent study found that even with a 50% reduction in current satellite transmission costs, the price tag for streaming data could be millions of dollars. Obviously in today's financial environment this is not the most economical solution to the problem. However the technology is available, and there are some military and commercial applications already in operation. So like many of the advances in aviation safety this may well become an accepted practice in the future.

10 Reporting Requirements for Safety Management Systems

If we return to the Air France accident, it has been reported that pitot failures were well known on the Airbus long-range fleet. Air France had reported problems to Airbus and Thales, the manufacturer of the pitot probes. The interim BEA investigation report documents the history of the probe issues, yet the possible high risk of these failures does not appear to have been recognised and certainly did not generate prompt corrective action. The risk assessment that is part of an effective Safety Management System did not identify the level of risk or the SMS was not implemented effectively.

There may have been several reasons for this. These reports were only a small part of the total reports received regarding Airbus aircraft operations. The critical step is to determine the severity and risk level associated with one or more reports and assesses the potential for a catastrophic outcome. This is a fundamental step in a safety management system.

In general everyday operations there is no shortage of occurrence reports and safety hazards identified by staff. Although we encourage open reporting of any safety concern, it is not always successful. From my experience, for example, an operator of 40 jet aircraft could expect 1,000 operational safety reports per year. Of these less than 5% would be considered other than minor, low risk. The most difficult task is how to ensure that the reports that could be indicative of a critical failure, in the right circumstances, are treated with the appropriate level of response. Risk ratings are used as the main tool, but these are open to interpretation. Experience and corporate knowledge can be essential in this process. Some types of occurrences have obvious risks and are rated reasonably consistently. However, other proactive (pre-emptive) safety concerns can be much harder to risk rate. The concern of a line pilot may be an isolated instance and then it becomes a difficult judgement issue. Very often these safety concerns are related to changes in procedures, processes, or documentation. The investigation often finds that change management procedures were not followed or were incomplete.

In Australia, the Australian Transport Safety Bureau [9] (ATSB) is the government safety investigation agency that has a mandatory reporting requirement. Any accidents or serious incidents, as defined by ICAO Annex 13, are immediately reportable including a death or serious injury, serious damage, or missing aircraft. However, the ATSB also has a list of further immediately reportable events that include such things as “airprox” (aircraft breakdown in separation), violation of controlled airspace, takeoff or landing on closed or occupied runways, uncontained engine failures, fuel exhaustion, undershooting, over running or running of the side of a runway amongst several other event types. The ATSB also has a class of reportable events called routine reportable, which have to be reported. These include injuries, other than serious, other than serious damage, a ground proximity warning system alert, runway incursion, and several other broad definitions related to aircraft performance, weather, loading, and air traffic system events. The result is the ATSB receives around 15,000 notifications per year on average, 8,000 of which are accidents, serious incidents or incidents, many of which do not get recorded. However the ATSB only carries out approximately 30 investigations per year. Less than 0.2% of reports are investigated. Another 0.2% [10] are published as Level 5 factual reports where the operators' internal investigation reports are edited and published.

With so many reports, there will be issues that warrant investigation but are not always obvious from one or two reports. A robust effective analysis system is essential to filter out the reports that can be indicative of a significant risk. The Australian Civil Aviation Safety Authority is taking a greater role in the process of safety investigation as it can no longer rely on the ATSB to investigate all serious or significant events. It is also concentrating on auditing the operator's safety management systems to ensure that the operator carries out a full and unbiased investigation so that safety lessons can be learned. For an effective Safety Management System there must be a full and robust safety investigation capability

11 Aviation Safety Challenges

A review of recent serious accidents shows that most were preventable. If accidents are analysed by broad category, then runway excursions and incursions, and loss of control, are the main types of accidents in recent years. If an effective Safety Management System is in operation by the regulatory authority, aerodrome operator or aircraft operator the numbers of these accidents should be minimised.

What is beginning to evolve is the complexity of flying highly automated aircraft when the automation starts to fail or gives erroneous indications. As we have seen from the Air France example what is apparent from some situations is that the failure modes and degraded status of some automated flight decks can be very confusing. It would appear that the designs do not provide as much help or guidance to the flight crew as they should. With multiple failures or erroneous data inputs generating various confusing, opposing signals, the automated systems should ideally review and advise the flight crew on the most optimum response. Also although modern flight decks make a positive contribution to safety performance, pilots are not as practised at manual flying as they used to be so that flying aircraft that have reverted to raw flight and navigational conditions becomes too demanding in difficult situations. Since the year 2000 serious accidents have frequently involved pilot failure to manage situations that they should really have been able to handle successfully. The year 2009 was no exception. Recent examples include the Turkish Airline Boeing 737-800 at Amsterdam, the Colgan Air Bombardier Q400 at Buffalo, New York, the FedEx Boeing MD-11F landing accident at Narita, Tokyo. Notice that we are not using the term "pilot error" but rather looking at the human performance issues, the system designs, the training, and lack of understanding of the degraded states of the automation. Hence the lessons from Erebus in 1979 are still very much part of safety investigation today.

Runway incursions and the complexity of air traffic control at major airports are becoming more frequent in safety statistics.

An Egyptian Boeing 777 flight that entered the runway into the path of a German Airbus A340 on the runway at JFK International airport, New York was just 37 feet from a catastrophe that could have claimed many hundreds of lives. The incident in June 2011 was the most dangerous near-miss of the year at the New York City airport, according to a report from the Federal Aviation Administration (FAA). The German flight carried 286 passengers bound for Munich. The Egyptian aircraft carried 346 passengers headed to Cairo. If they had collided, it could have been the worst commercial air disaster in history.

Many capital city aerodromes are very busy and congested. There is no shortage of data about actual and potential runway incursions.

For example

Incursion incident at Okinawa

A serious runway incursion incident at Okinawa, Japan on July 5, 2012, when an Air Asia Japan flight had been cleared to land on the active runway at Okinawa-Naha Airport (OKA). At the same time, China Eastern Airlines flight MU2046 had been instructed to hold short in preparation for take-off on a scheduled passenger flight to Shanghai-Pudong Airport, China. Flight MU2046, operated by an Airbus A319, registered B-2332, taxied onto the active runway instead of holding short. The Airbus A320, of Air Asia, registered JA01AJ, was 5.6 km out and was instructed by ATC to go around.

What is needed are effective safety management systems which analyse the runway incursion data and build in procedural and physical barriers to prevent incursions. There are also technological advances for aircraft and air traffic controllers which can warn of potential risks of incursions. Ground based radar surveillance and on board traffic positional information could prevent these aerodrome operational risks.

Historically, improvements have come largely from better equipment and pilot training. Experts believe that in the future, however, the biggest advances will come primarily from analysing huge volumes of data about a broad array of incidents, culled from multiple carriers across the globe, a global Safety Management System.

Early versions of such forward-looking data analysis played a major role in cutting U.S. accident rates since the late 1990s, and they are being embraced by regulators and airline executives in scores of other countries. Now, the FAA and U.S. carriers are trying to involve foreign counterparts in similar dissection of safety data retrieved from actual flights and voluntary pilot reports. The trend is gaining particular momentum in Russia and across Latin America.

Yet sharing safety data across borders poses huge technical and legal challenges. As a result, not a single foreign carrier is fully participating in - or providing safety data for - the FAA's most ambitious threat-analysis system. In seeking common causes of crashes around the world, "no longer is there a clear distinction between domestic and international accidents," said the head of the U.S. National Transportation Safety Board, at a speech to the United Nations' aviation body in Montreal.

11 Conclusion

In aviation we are very proud of our safety record and the advances in safety over the years through technology and improving human performance. We are often compared with other modes of travel, and depending how you analyse the statistics, aviation comes out as the model for safety. However, as many analysts have commented we may have reached a plateau, and further improvements may be very hard.

In conclusion, there have been many important advances in technology, in systems, in understanding, and influencing human behaviours and in safety assurance. However, it appears that we have reached a plateau in the quest for improved safety. We still have accidents that have the same elements of many previous ones and should therefore have been preventable. There is no shortage of reports, but the challenge for safety investigators is to have effective Safety Management Systems through detailed investigation findings and actions so that we can eliminate accidents such as runway excursions, loss of control, and CFIT once and for all.

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