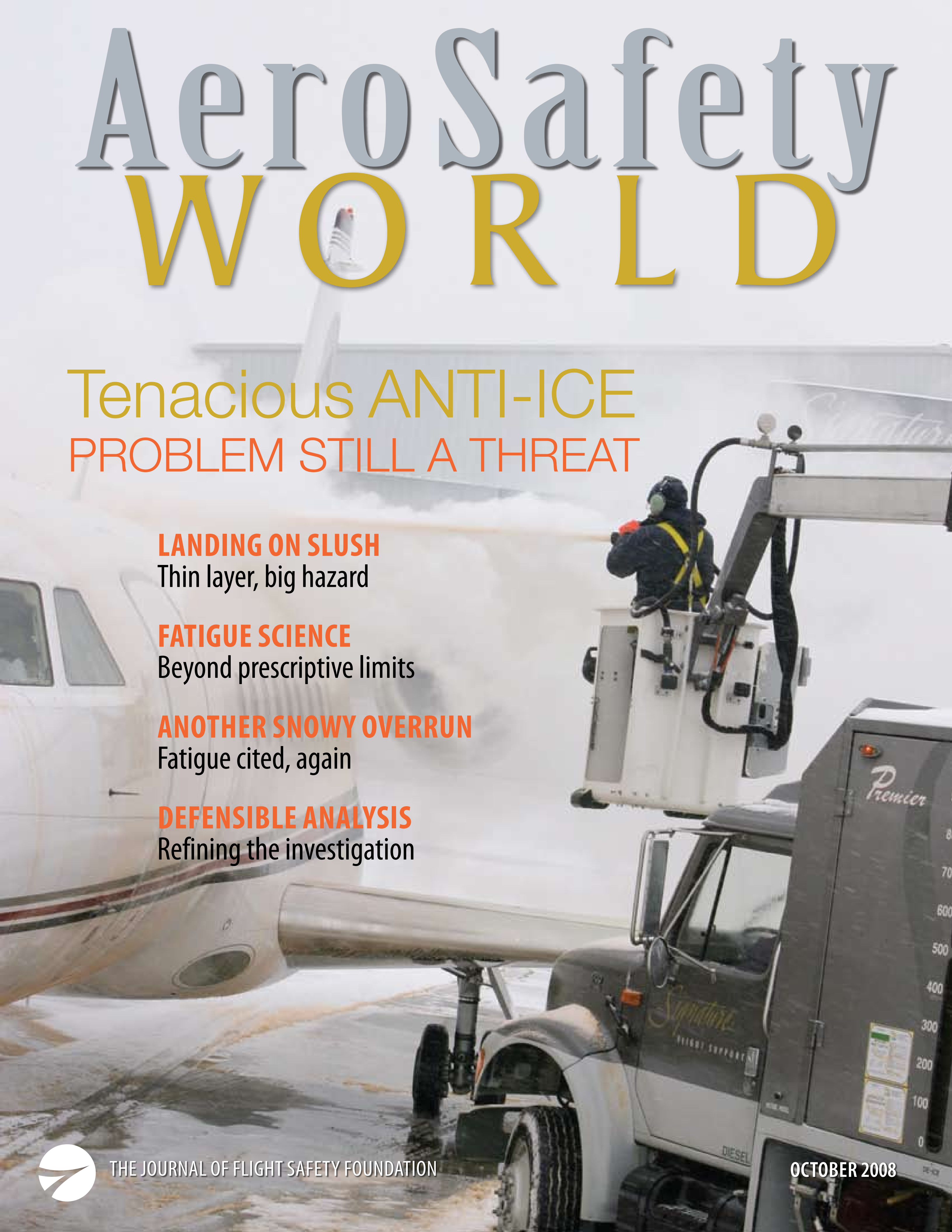
AeroSafety WORLD



Tenacious ANTI-ICE PROBLEM STILL A THREAT

LANDING ON SLUSH
Thin layer, big hazard

FATIGUE SCIENCE
Beyond prescriptive limits

ANOTHER SNOWY OVERRUN
Fatigue cited, again

DEFENSIBLE ANALYSIS
Refining the investigation

THE JOURNAL OF FLIGHT SAFETY FOUNDATION

OCTOBER 2008

LEARNING FROM History

I hate to rely on overused literary references, but recent events compel me to do just that. In 1905, philosopher George Santayana said, "Those who cannot remember the past are condemned to repeat it." It seems that, lately, aviation has been repeating more than a few dark moments from the past. As I write, investigators in Spain are considering the possibility that the recent crash of a Spanair McDonnell Douglas MD-82 may have been a case of improper setting of slats and flaps on takeoff. That same scenario resulted in the deadly crash of an MD-80 in Detroit in 1987. That is a very personal memory for me. I was an air traffic controller in Detroit at the time and helped support that investigation. The crash in Spain brings back sights, smells and emotions that had been filed away for a long time. It is difficult to even consider the possibility that a decades-old tragedy could repeat itself in this day and age of safety improvements.

Unfortunately, that is not the only case of repetition that lately has come to my attention. Just a few weeks ago, I was in Taipei, Taiwan, watching a presentation from a young aviation occurrence investigator. He was pointing out this same unfortunate pattern of ignored warnings and repeated mistakes. One example he cited was the crash of an Avions de Transport Regional (ATR) 72 in Roselawn, Indiana, U.S., in 1994, caused by icing. Then he listed seven similar incidents and accidents that have occurred since then in icing conditions with ATR 42s and ATR 72s. Two weeks later, I was in Norway, listening to a briefing from another investigator. She described another serious incident she was investigating, involving one of the same model aircraft under similar circumstances.

We see this "forgetful pattern" in ongoing work at the Foundation. Our recent efforts to put together a tool kit for runway excursions keep pointing us back to old lessons that have been learned too many times at the cost of too many lives, often basic lessons about stabilized approaches and the proper use of braking and reverse thrust.

We have achieved great safety improvements over the past several decades by predicting problems before they turn into tragedies. *Predicting* is important, but there is something always to be gained by *remembering,* as well. To a great extent, that is one of the things we do in this magazine. We detail the hard-won lessons of the past to share them with the rest of the world. At the Foundation, we do our part by making this publication available electronically, free, for anyone who wants it.

Many companies put out in-house safety publications of their own, which have great value in being able to focus on the specifics of that firm's operations. But as our industry faces difficult financial times, and looks for even more places to cut costs, aviation executives around the world need to be warned: That safety newsletter filled with accounts of incidents and "war stories" is not a luxury that can be cut without risking severe consequences. That small budget line is the cost of remembering. The cost of forgetting is something that no company can afford.

William R. Voss
President and CEO
Flight Safety Foundation

AeroSafetyWORLD

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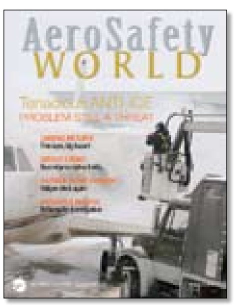

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Some anti-icing fluid formulas create control problems.
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AeroSafetyWORLD

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EXPANDING Trust

We lately have printed several stories in which pilots or complete crews were so fatigued that, when they needed to make good decisions quickly, they could not come up to their typical level of performance. (See, for example, *ASW*, 9/08, p. 22.) The ensuing events ranged from fatal accidents to equipment-damaging overruns. To me, the alarming aspect of these events is further evidence of a widespread state of affairs that, largely by neglect, results in crews flying too exhausted to function correctly.

Sometimes, it is a matter of a particular pilot who, for a range of reasons, could not get the rest he or she knew was needed. Sometimes, it is a matter of scheduling practices that put crews in a position where a minor disruption at the end of a long duty day pushes them past the tipping point to exhaustion. Usually, exhausted crews rely on their professionalism to bring their day to a successful conclusion, all the system safeguards providing a sufficient margin. And, sometimes, the negatives overwhelm what's left of the safety defenses and the final result is not good.

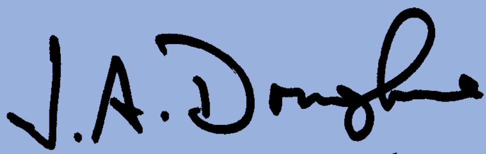
In asking why these conditions persist, I clearly am pushing into territory littered with landmines left from decades of labor-management wars. The institutional elements of this issue are too varied for this space, but in the case of scheduling rules, each group often feels abused by the other. An individual's fatigue is different and gets wrapped around management resistance to giving special treatment.

The particulars of this process are varied, but one element that permeates this discussion, with rare exceptions, is bedrock distrust between the two groups.

Until about 20 years ago, that distrust went across the board. But then an insidious little guerilla action started on the fringes, attacking advanced outposts of distrust as safety initiatives worked to develop new ways to identify and mitigate threats before they became accidents. The movement came in many forms, forms that in some cases were so revolutionary they required laws to be changed before they could become practice. There were many names, many programs, and they all depended on management convincing pilots that these were not just new sleazy ploys to be used as leverage in the constant battle between the two groups, and pilots convincing management that these programs were not just new ways of avoiding responsibility. Neither was an easy sell. Yet, today we have a fairly elaborate safety reporting and signaling system dependent on a foundation of trust between the two groups — regulators, too, but that's outside of this discussion.

I am suggesting it is time to advance the trust offensive. The difficulty a crew or individual pilot faces in calling a time-out on account of being too tired to be safe is greater than it should be, especially since most regulators require pilots to stop flying when they are aware of their degraded abilities.

How is it that an airline or corporate flight department can operate with a just culture in all other operational elements, with trust flowing both ways, yet on the issue of scheduling, sick time and even fatigue we find the system locked into rigid structures dating from the industrial revolution? That's illogical and inappropriate in today's aviation system.



J.A. Donoghue
Editor-in-Chief
AeroSafety World

Serving Aviation Safety Interests for More Than 60 Years

Flight Safety Foundation is an international membership organization dedicated to the continuous improvement of aviation safety. Nonprofit and independent, the Foundation was launched officially in 1947 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 1,170 individuals and member organizations in 142 countries.

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OCT. 4–5 ➤ Flight Operations Manual Workshop: Employing the International Standard for Business Aircraft Operations. National Business Aviation Association. Orlando, Florida, U.S. Sarah Dicke, <sdicke@nbaa.org>, <web.nbaa.org/public/cs>, +1 202.783.9000.

OCT. 6–8 ➤ 61st Annual Meeting and Convention. National Business Aviation Association. Orlando, Florida, U.S. Donna Raphael, <draphael@nbaa.org>, <web.nbaa.org/public/cs/amc/2008>, +1 202.783.9000.

OCT. 6–8 ➤ Airport Wildlife Managers Course. American Association of Airport Executives and Minneapolis-St. Paul International Airport. Minneapolis. Alex Gertsen, <alex.gertsen@aaae.org>, <events.aaae.org/sites/081001>, +1 703.824.0500, ext. 183.

OCT. 7–9 ➤ Aircraft Accident Investigation Course. University of North Dakota Aerospace Foundation and Air Line Pilots Association, International. Grand Forks, North Dakota, U.S. Frank Argenziano, <argenzia@aero.und.edu>, +1 701.777.7895.

OCT. 8 ➤ Safety Management Systems Workshop. European Regions Airline Association. Manchester, England. Jean-Pierre Fleitou, <jpfleitou@regional.com>, <www.eraa.org/inside-era/generalassembly/Workshop/safetymanagework.php>, +33 (0)240 135 410.

OCT. 9 ➤ Contingency Planning Workshop. European Regions Airline Association. Manchester, England. Jean-Pierre Fleitou, <jpfleitou@regional.com>, <www.eraa.org/inside-era/generalassembly/Workshop/contingencywork.php>, +33 (0)240 135 410.

OCT. 8–9 ➤ 3rd Aviation Emergency Response Conference. Association of Asia Pacific Airlines. Hong Kong. <www.aapairlines.org/AAPA_3rd_Aviation_Emergency_Response_Conference.aspx>.

OCT. 9 ➤ Maintenance Manual Workshop. National Business Aviation Association. Orlando, Florida, U.S. Donna Raphael, <draphael@nbaa.org>, <web.nbaa.org/public/cs>, +1 202.783.9000.

OCT. 13 ➤ Helicopter Safety Conference. European Helicopter Safety Team. Estoril, Portugal. Savina Zakoula, <communications@easa.europa.eu>, +49 221 89990 2008; Kay Brackins, <kay@vtol.org>, +1 703.684.6777, <www.ihst.org/index.php?option=com_content&task=view&id=47&Itemid=2>.

OCT. 15–17 ➤ Wildlife Hazard Management Workshop. Embry-Riddle Aeronautical University. Portland, Oregon, U.S. Allen R. Newman, <newmana@erau.edu>, <www.erau.edu/ec/soctapd/wildlife-management.html>.

OCT. 15–18 ➤ 25th International Meeting of Aerospace Medicine. Mexican Association of Aviation Medicine and the Iberoamerican Association of Aerospace Medicine. Zacatecas, Mexico. Luis A. Amezcua Gonzales, M.D. <lamezcua@att.net.mx>, <www.amma.org.mx>, +52-55 55.23.82.17.

OCT. 20–22 ➤ Air Medical Transport Conference. Association of Air Medical Services. Minneapolis. <www.aams.org/AM/Template.cfm?Section=Education_and_Meetings>, +1 703.836.8732.

OCT. 21 ➤ Accident Prevention via Human Factors Training. National Air Transportation Association. San Diego. <www.nata.aero/events/event_detail.jsp?EVENT_ID=1582>.

OCT. 21 ➤ Safety Management Systems Overview. MITRE Aviation Institute. McLean, Virginia, U.S. Cheryl Andrews, <andrewsc@mitre.org>, <mai.mitrecaasd.org/sms_course>, +1 703.983.6275.

OCT. 23–24 ➤ 5th Flight Safety Seminar on Confidential Report Systems. Spanish Professional Pilot Association (COPAC). Madrid. <comunicacion1@copac.es>, <www.copac.es>, +34 91 590 02 10.

OCT. 27–30 ➤ International Air Safety Seminar (IASS). Flight Safety Foundation, International Federation of Airworthiness and International Air Transport Association. Honolulu. Namratha Apparao, <apparao@flightsafety.org>, +1 703.739.6700, ext. 101.

OCT. 27–31 ➤ EAAP Conference 2008. European Association for Aviation Psychology. Valencia, Spain. <eaap@dlr.de>, <www.eaap.net/conferences>, +49 40-5130960.

OCT. 27–29 ➤ 46th Annual Symposium. SAFE Association. Reno, Nevada, U.S. Jeani Benton, <safe@peak.org>, <www.safeassociation.com>, +1 541.895.3012.

OCT. 30–31 ➤ Airport SMS: From FAA Pilot Program to Implementation. American Association of Airport Executives, The MITRE Corp., Airports Council International–North America and the U.S. Federal Aviation Administration. Baltimore. <events.aaae.org/sites/080703>.

NOV. 2–5 ➤ ATCA 53rd Annual Conference and Exposition. Air Traffic Control Association. Washington, D.C. Claire Rusk, <claire.rusk@atca.org>, <www.atca.org/event_items.asp?month=10&year=2008&comm=0>, +1 703.299.2430.

NOV. 10–12 ➤ ATAC 2008 Annual General Meeting & Trade Show. Air Transport Association of Canada. Calgary, Alberta. <atac@atac.ca>, <www.atac.ca/en/events/agm/index.html>, +1 613.233.7727.

NOV. 11–12 ➤ European Aviation Training Symposium (EATS): Exploring and Promoting European Best Practice in Aviation Training and Education. Halldale Media. Vienna, Austria. Chris Lehman, <chris@halldale.com>, <www.halldale.com/EATS.aspx>, +44 (0)1252 532000.

NOV. 11–12 ➤ Airline Safety, Quality and Technical Training Conference. Aviation Industry Conferences. Dubai, United Arab Emirates. Juliet Trew, <juliett@aviation-industry.com>, <206.18.175.32/ME2/Audiences>, +44 (0)207 931 7072.

NOV. 12–14 ➤ AAAE Runway Safety Summit. American Association of Airport Executives. Fort Lauderdale, Florida, U.S. Alex Gertsen, <alex.gertsen@aaae.org>, <www.aaae.org/products/meeting_details.html?Record_id=587>, +1 703.824.0500.

NOV. 17–21 ➤ SMS Principles. MITRE Aviation Institute. McLean, Virginia, U.S. Cheryl Andrews, <andrewsc@mitre.org>, <mai.mitrecaasd.org/sms_course>, +1 703.983.6275.

NOV. 18–19 ➤ Air Safety Work Group. European Regions Airline Association. Valencia, Spain. Jean-Pierre Fleitou, <jpfleitou@regional.com>, <www.eraa.org/inside-era/eraevents.php>, +33 (0)240 135 410.

Aviation safety event coming up? Tell industry leaders about it.

If you have a safety-related conference, seminar or meeting, we'll list it. Get the information to us early — we'll keep it on the calendar through the issue dated the month of the event. Send listings to Rick Darby at Flight Safety Foundation, 601 Madison St., Suite 300, Alexandria, VA 22314-1756 USA, or <darby@flightsafety.org>.

Be sure to include a phone number and/or an e-mail address for readers to contact you about the event.

Diagnosing What Hasn't Happened Yet

Bill Voss's editorial (*ASW*, 7/08, p. 1) prompts these comments.

While a safety management system (SMS) is a great process, that does not mean every organization should do it in the same way. Each SMS should be tailored as a function of the James Reason risk/defense model of that organization.

An original equipment manufacturer (OEM) for aircraft, engines or propellers usually has — at least in Europe — a design organization approval (DOA) and a design organization manual. Both follow strict regulatory rules. The processes used mimic SMS processes almost one to one, but are mostly valid for "Reason" defenses: management (fallible decisions); organization (error-inducing structure); and conditions (psychological factors). So, primarily, latent failures.

Airlines, airports and ATC perform millions of operations per day, so are heavily involved in production and last defenses (both active and latent failures).

That does not mean that an OEM does not have incidents, but they are of an entirely different nature and magnitude (tens versus millions of events). Furthermore, there are strict processes for dealing with these nonconformance reports.

No matter how good the SMS or DOAs, any organization will be faced with two major issues: In which domain is the incident, accident or issue, i.e. historic, diagnostic or prognostic? And is the CEO of the organization prepared to spend the money?

As we move from historic to diagnostic to prognostic, the difficulty of making that investment decision gets progressively tougher. While industry already has a hard time incorporating, for example, all fuel flammability measures, let alone introducing nitrogen inerting following the TWA Flight 800 accident [July 1996], this will turn into a monumental process to spend money on a defense for something that has yet to develop into a full-blown crisis, such as UAVs [unmanned aerial vehicles] crashing into other aircraft or on cities, or widespread hacking and/or inadvertent malignant viruses affecting aircraft computer systems such as data base updates of electronic flight bags via the Internet.

We also appear not smart enough to have a diagnostic event-finding structure in place to catch the events that preceded the British Airways Boeing 777 accident at Heathrow [January 2008]. I will bet that eventually someone will find that the accident precursors were there but not noticed.

The problem we face today is that safety is at a standstill because of the scarcity of accidents, hence the aerospace industry is not learning anymore, so we have to face these difficult issues and come to grips with them if we want to improve safety.

Rudi den Hertog
Chief engineer
Fokker Services

AeroSafety World encourages comments from readers, and will assume that letters and e-mails are meant for publication unless otherwise stated. Correspondence is subject to editing for length and clarity.

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Safety News

Anti-Icing Recommendations

Restricted fuel flow, probably caused by ice in the fuel feed system, led to the Jan. 17 crash of a British Airways Boeing 777-200ER just short of the landing runway at London Heathrow Airport, the U.K. Air Accidents Investigation Branch (AAIB) said in a report that recommended interim measures to reduce such risks in the future.

One of the 152 people in the airplane was seriously injured in the crash, and 12 received minor injuries. The airplane was destroyed.

In its interim report on the accident, the AAIB said that ice likely formed in the fuel during the long Beijing-to-London flight, conducted with low fuel flows and in an "unusually cold" environment in which the fuel temperature was as low as minus 34 degrees C (minus 29 degrees F). The report noted that the flight was operated within certified operational limits at all times.

"All aviation fuel contains water which cannot be completely removed, either by sumping or other means," the report said. "Therefore, if the fuel temperature drops below the freezing point of the water, it will form ice. The majority of flights have bulk fuel temperatures below the freezing point of water, and so there will always be a certain amount of ice in the fuel."

The AAIB recommended that the European Aviation Safety Agency (EASA) and the U.S. Federal Aviation Administration (FAA), working with Boeing and Rolls-Royce, the manufacturer of the accident airplane's Trent 895-17 turbofan engines, "introduce interim measures … to reduce the risk of ice formed from water in aviation turbine fuel causing a restriction in the fuel feed system."


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In response, the EASA said that it will work with the FAA to define acceptable interim measures.

Other recommendations called on the EASA and the FAA to "consider the implications of the findings of this investigation on other certificated airframe/engine combinations" and "review the current certification requirements to ensure that aircraft and engine fuel systems are tolerant to the potential buildup and sudden release of ice in the fuel feed system."

The EASA and the FAA have begun the reviews to evaluate the implications of the findings for other airframe-engine combinations and will review the need for future rule-making action.

The AAIB investigation of the accident is continuing.

Qantas Safety Review

Qantas officials have been told to develop a plan to address deficiencies in meeting maintenance performance goals. The Civil Aviation Safety Authority of Australia (CASA) says that a number of improvements are needed as a result of a special CASA review of the airline.

The review followed several safety incidents involving Qantas aircraft, including a July 25 incident in which a section of the fuselage separated from a Boeing 747-400 while the airplane was at 29,000 feet en route from Hong Kong to Melbourne, Australia. The separation resulted in a rapid decompression and diversion to Manila, Philippines, where the airplane was landed safely. No one was injured in the incident. A preliminary report by the Australian Transport Safety Bureau said that the fuselage ruptured after a passenger oxygen cylinder burst.

CASA also told Qantas that it must examine "whether the existing lines of authority and control over maintenance within the airline are delivering the best possible outcomes."

While Qantas completes these tasks, CASA will conduct two more audits of the airline. The first is designed as a full maintenance audit of one airplane from each major airplane type being used by the airline — 747-400s, 737-400s and 767-300s — to ensure that all maintenance documentation has been completed. The second audit will examine the effectiveness of the airline's maintenance systems in managing and implementing airworthiness directives.

"By taking action now, future safety problems will be avoided," said Mick Quinn, CASA deputy chief executive officer. "The wide-ranging actions CASA has initiated will prevent any downward trend in Qantas maintenance performance."


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Aid for Search-and-Rescue Efforts

U.S. Coast Guard

The Canadian government is proposing regulatory changes to require aircraft to be equipped with an emergency locator transmitter (ELT) that operates on 406 MHz, instead of the existing requirement for an ELT that can transmit on 121.5 MHz.

The proposed regulation also would allow an alternative means of emergency notification, as long as it is equivalent in performance to the 406 MHz ELT.

Lawrence Cannon, minister of transport, infrastructure and communities, described the 406 MHz equipment as "the aircraft's lifeline to search-and-rescue services."

The new regulations would bring Canadian requirements in line with those of the International Civil Aviation Organization, which currently requires 406 MHz ELTs on all international commercial passenger aircraft and recommends their use on all other aircraft beginning Feb. 1, 2009. On that date, the International Cospas-Sarsat Programme, which coordinates the detection of distress signals, will no longer monitor distress signals from 121.5 MHz ELTs.

Cospas-Sarsat says current digital 406 MHz beacons, which can transmit unique beacon identifications and position information acquired from global navigation satellite systems, relay positions of aircraft (and ships) in distress faster and more accurately than 121.5 MHz beacons.

'Mixed Picture' of Australian GA

General aviation in Australia is an industry in transition, according to a report released by Federal Infrastructure and Transport Minister Anthony Albanese.

"While parts of the industry are growing and prospering, some smaller operators are struggling to remain viable," Albanese said. "The commercialization of general aviation airports, skill shortages, a complex regulatory environment and the aging of the small aircraft fleet have all created a challenging operating environment."

The report includes 18 recommendations, among them suggestions to improve awareness of general aviation in the government's existing business assistance programs and to establish targets for growth in the exporting of aviation services. The report said that the industry supports CASA's efforts to become "a more effective and efficient regulator" and that there is little support for self-regulation.

Brake Inspections

An Indonesian investigation of an incident involving a main landing gear failure on a Boeing 737 has led to a series of safety recommendations by the Indonesian National Transportation Safety Committee (NTSC), calling for inspections of 737-200/300/400/500 series airplanes with more than 15,000 cycles since overhaul to check for cracks in brake mounting holes.

The landing gear failure, which occurred in Banjarmasin on July 23, involved a crack in a brake mounting hole. The landing gear assembly on the incident airplane had been in service for 15,218 cycles. The Boeing overhaul manual calls for inspections of the area at intervals not exceeding 21,000 cycles or 10 years in service.

NTSC recommendations say the Indonesian Directorate General Civil Aviation should require Indonesian operators of the affected airplanes to conduct one-time nondestructive tests, followed by eddy current inspections during each "C" check; the inner cylinder/sliding member assemblies should be replaced if a crack is found in one or more brake mounting holes or other parts of the assembly.

Similar recommendations were issued to the European Aviation Safety Agency, the U.S. Federal Aviation Administration and Boeing.

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Safety Improvement Program

The U.S. Federal Aviation Administration (FAA) has been told to implement 13 new recommendations developed by an independent team that reviewed the U.S. aviation safety system.

Transportation Secretary Mary E. Peters said the recommendations, being implemented immediately, would "improve both the intensity and the integrity of the FAA's safety program."

One recommendation says that the FAA "should retain the right to ground any plane not in compliance with an applicable AD [airworthiness directive]," and should not be expected to conduct a risk assessment before taking action.

Another recommendation calls for the FAA to have guidance in place by the end of the year to "ensure that airworthiness directives and their deadlines are fully understood by all appropriate FAA officials and airlines." A third calls for "more rigorous and systematic oversight" of the FAA voluntary disclosure program. For the most part, however, the report affirmed the current safety system and especially the voluntary reporting programs.

Flight Safety Foundation praised the recommendations and urged the FAA to implement them quickly.

"The current regulatory approach to aviation safety in the United States is working and is a model for civil aviation authorities around the world," said Foundation President and CEO William R. Voss. "But that does not mean that there shouldn't be an occasional review to see if there are ways to make the FAA safety programs even more effective. The recommendations … are solid and should be implemented."

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The Foundation is a leading proponent of the need for a free flow of information among all segments of the aviation industry and says U.S. air carriers have developed an excellent safety record in part because pilots and management are able to review flight information and collaborate with regulators "so that the causes of minor incidents during normal flight operations can be identified and corrected before a major accident occurs."

In Other News …

The **U.S. Federal Aviation Administration's** audits of airworthiness directives at U.S. air carriers have found an overall compliance rate of 98 percent, the agency says. … The **Civil Aviation Safety Authority of Australia** (CASA) has proposed regulations for the issuance of multi-crew pilot licenses (MPL). A notice of proposed rulemaking says the minimum MPL aeronautical knowledge requirements should be the same as the requirements for obtaining an air transport pilot license and instrument rating. … The **South Korean** aviation system has received a score of 98.82 out of 100 in the Universal Safety Oversight Audit Programme (USOAP) audit by the International Civil Aviation Organization (ICAO) — the highest score of 108 countries evaluated. The score reflected improvement since ICAO's first audit in 2000, when South Korea ranked 53rd with a compliance rating of 79.79. … **Gulf Air** has adopted the Aviation Quality Database (AQD) Safety Management System, an integrated safety, quality and risk management system that combines quality and assurance auditing with flight, cabin maintenance and ground safety occurrence reporting.

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Eclipse Recommendations

The U.S. Federal Aviation Administration (FAA) has accepted the recommendations of a panel that reviewed certification of the Eclipse EA500 very light jet (VLJ). The six recommendations included a call for the FAA and the manufacturer to analyze trim actuator failures being reported by operators.

The panel said that technical problems are common during certification of a new airplane, but "a lack of commonly used internal FAA documentation caused the perception that the aircraft might not have been properly certified." The panel also cited "a lack of effective communication between Eclipse and the FAA, and between the responsible offices within the agency."

Acting FAA Administrator Robert A. Sturgell said that the panel's comments will be "invaluable as we continue certifying these new types of aircraft."

Compiled and edited by Linda Werfelman.

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Treacherous THAWING

BY REINHARD MOOK

Slush may induce poor/nil aircraft braking action, contrary to runway friction readings.

One of the most slippery runway conditions possible may occur if aircraft tires fail to penetrate a layer of slush to contact the paved surface. This risk is not news, but global warming may result in more frequent encounters with slush even in the coldest regions. Four winters of research on the deceleration of commercial transport airplanes landing at one airport in Norway found that temporary loss of directional control could occur when the slush was 3 mm (0.12 in) deep.

Mechanical consistency is the physical property of slush most relevant to braking, yet sand applied to slush by airport operators barely improved airplane braking. The research airport's Skiddometer, a continuous friction measurement system, in frozen-contaminated wet

conditions typically indicated significantly better aircraft braking action than could be achieved.[1]

It turns out that a *derived airplane braking coefficient* no better than 0.04 to 0.06 — corresponding to "poor/nil" braking action reports — might be expected while skidding/hydroplaning on any combination of liquid water and ice fragments, and in the case of tires lifted off the paved surface by an air-ice mixture, this coefficient can drop even below 0.04 (Table 1, p. 16).

Landings by Boeing 737-400s, 737-500s, 737-700s and 737-800s were observed and analyzed during the winters of 2004–2005 through 2007–2008 at Svalbard Airport Longyear. With few exceptions, flights were canceled or diverted when the Skiddometer friction coefficients were in the lower end of the 0.30s. When no aircraft arrived, no airplane braking coefficients could be derived for the data set.[2]

Not considered during the Svalbard research were the autobrake setting, the manual braking technique or the landing weight. The vector component of wind along the runway also was not taken into account in calculating the time needed for braking to a stop on slush. As a consequence, the derived airplane braking coefficients in the table are only estimates.

At the microscopic level, slush is flexible tiny fragments of ice lubricated by liquid water, with the fragments usually rounded by melting. The most important effect of slush on deceleration is the reduced shear forces between the tires and the runway pavement during braking. Thus, as a rule, deceleration on slush is influenced significantly by sliding or skidding. A recent report by the Accident Investigation Board Norway (AIBN) found that, due to the predominance of gliding friction when operating on slush, the airplane braking coefficient does not depend on aircraft velocity.[3]

Shear forces decrease, for example, when the slush layer rests on an icy base with melting at the common boundary. Another type of boundary layer — liquid water below a slush base — may result from gravity or from compaction by the tire footprint squeezing the slush.

Another factor is *flood resistance* — resistance to a rolling wheel by a plowing process, such as the displacement of slush — and the impingement of slush, including spray, against the aircraft — both contributing substantially to aerodynamic drag forces.

How Slush Forms

Slush may accumulate directly by precipitation, depending on generating processes in the cloud region, and the air temperature and water vapor in the lower troposphere. Slush also may form indirectly from sleet or snow followed by rainfall, or snow and rain falling intermittently. Snow precipitated into a film or a shallow layer of standing water also can change to slush by capillary force and water adsorption.

In other cases, starting with a snow layer, a heat input can induce melting and transform the snow to slush. This heat can be stored in and released from the asphalt or concrete runway. Snow also can be heated when solar radiation penetrates a snow layer or ice layer and is absorbed partly in this layer and partly in the pavement surface. Mechanically weak ice crystal aggregates easily can be broken up by the loads applied by aircraft and vehicles.

When chemicals are spread over a dry runway to melt snow as it falls, if the snowfall exceeds the melting rate and water drains, snow will accumulate. If snow falls on a film of melting snow, the result is white snow seen from the air that covers and hides the likely presence of slush. This article assumes water freezing at 0 degrees C (32 degrees F). In the case of chemical treatment, slush may be present even at air temperatures considerably below freezing. Separation of the frozen aggregates, chemical salts and liquid water in this scenario results in the aircraft wheel's load acting on a spongy, slimy form of slush.

A molecular film of slush may even be generated for an extremely brief time when the surface is heated to melting temperature at the contact areas between a tire heated by friction as it moves and the ice or compacted snow on a runway. Similarly, hoar frost and loose snow crystal fragments left on a runway after snow-removal operations on a microscopic scale may change to slush for an extremely brief time.

Predicted and Measured Deceleration on Contaminated Runway

Runway Condition	Landings Measured	Runway Environment Temperatures: Air °C/°F	Dew Point °C/°F	Frost Point °C/F	DP Spread °C/°F	FP Spread °C/°F	Surface Contamination °C/°F	Runway Braking Coefficients: Derived Airplane Braking Coefficient: Min	Mean	Max	Skiddometer Friction Coefficient: Min	Mean	Max
A. Slush on asphalt	5	2.9/37.2	1.9/35.4	—	1.0/1.8	—	0/32	0.05	0.06	0.07	0. 29	0.34	0.38
The slush depth was 1 mm (0.04 in) without sanding for four landings and 3 mm (0.12 in) with sanding for one landing. A head wind of 13 kt was measured. Weather included low clouds with a rain-snow mix (sleet) during four landings and rain during one landing.													
B. Slush on ice or compacted snow	9	2.1/36.8	0.4/32.7	—	1.7/4.1	—	0/32	0.04	0.05	0.07	0.30	0.36	0.41
The slush depth was 1 mm with sanding for seven landings and 3 mm with sanding for two landings. A head wind of 11 kt was measured. Weather included broken low and middle-high clouds with rain during four landings, sleet during three landings and wet-runway conditions after precipitation during two landings.													
Exception	1	6.2/43.2	—	−1.2/29.8	—	7.4/13.4	0/32	—	0.08	—	—	0.32	—
Compacted snow transformed to slush to a maximum depth of 2–3 mm with sanding. A head wind of 5 kt was measured. Weather included a few middle-high clouds and sunshine.													
C. Water on ice or compacted snow	2	2.8/37.0	1.3/34.3	—	1.5/2.7	—	0.2/32.4	0.04	0.05	0.06	0.27	0.30	0.35
The runway cover was 1 mm water with sanding for both landings. A head wind of 15 kt was measured. Weather included an overcast of low clouds, rain and/or wet-runway conditions after rain.													
Exception	1	2.5/36.5	—	−3.3/26.1	—	5.8/10.4	0.3/32.5	—	0.06	—	—	0.34	—
The runway cover was 1 mm water on soggy ice. A head wind of 9 kt was measured. Weather included broken middle-high clouds and high clouds and wet-runway conditions after rain.													
D. Ice or compacted snow with "dry" surface	13	−4.1/24.6	—	−7.5/18.5	—	3.4/6.1	−6.8	0.08	0.11	0.13	0.32	0.38	0.47
The runway cover was loose or hard-frozen snow with sanding for all landings. A head wind of 7 kt was measured. Weather included scattered middle and/or high clouds with no precipitation.													
Exception	3	−3.5/25.7	—	−5.8/21.6	—	2.3/4.1	−7.0/19.4	0.06	0.07	0.08	0.34	0.37	0.41
The runway cover was the same as for the 13 landings above. A head wind of 6 kt was measured. Weather included broken middle-high clouds with no precipitation.													
E. Extremely cold ice or compacted snow with "dry" surface	9	−14.2/6.4	—	−18.8/−1.8	—	4.6/8.2	−17.4/0.7	0.12	0.14	0.18	0.38	0.45	0.51
The runway cover was frozen hard and sanded for all landings. A head wind of 10 kt was measured. Weather included clear sky or few high or middle-high clouds with no precipitation.													
F. Drifting snow on stationary compacted snow	5	−8.9/16.0	—	−13.0/8.6	—	4.1/7.4	−11.8/10.8	0.05	0.07	0.09	0.34	0.36	0.40
The runway cover was frozen hard with partial sanding for all landings. A head wind of 21 kt was measured. Weather included middle-high clouds and high clouds, with drifting snow and no precipitation.													
G. Blowing snow on stationary compacted snow	3	−15.1/4.8	—	−17.0/1.4	—	1.9/3.4	−16.0/3.2	0.03	0.03	0.04	0.32	0.38	0.48
The runway was covered by drifting snow and partially sanded for all landings. A two-minute head wind of 28 kt was measured. Weather included scattered middle-high clouds with no precipitation.													
H. Recent snow on ice or compacted snow	4	−2.3/27.9	—	−3.4/25.9	—	1.1/2.0	−3.8/25.2	0.04	0.06	0.07	0.29	0.32	0.36
The runway cover was less than 10 mm (0.4 in) snow with sanding for all landings. A head wind of 10 kt was measured. Weather included scattered low clouds and middle-high clouds, with snow falling or snowy conditions after snowfall.													
I. "Black" asphalt with dry surface	8	−4.4/24.1	—	−9.5/14.9	—	5.1/9.2	1.2/34.2	0.18	0.21	0.23	—	—	—
The runway was free of contaminants and sand for all landings. A head wind of 4 kt was measured. Weather included clear sky or scattered high clouds with temporary direct solar radiation.													

Min = minimum value; Max = maximum value; DP = dew point; FP = frost point; — = not relevant

Notes: *Spreads* are the difference between air temperature and dew point temperature or between air temperature and frost point temperature. Air temperature, dew point temperature and frost point temperature were measured 2.0 m (6.7 ft) above ground level. *Surface contamination* means the surface temperature of the contamination — 0 degrees C/32 degrees F for slush, ice or compacted snow bordering slush or water. Standing water may have a higher temperature. The *derived airplane braking coefficient* was calculated from measurements of actual deceleration during landings of Boeing 737-400s, 737-500s, 737-700s and 737-800s. The *Skiddometer friction coefficient* readings were taken from section B of Runway 10/28 at Svalbard Airport, Longyear, Norway, using a Skiddometer BV11, a continuous friction measurement system towed behind an airport vehicle. All numbers are arithmetic means except where noted. Data were collected during winters 2004–2005 through 2007–2008.

Source: Reinhard Mook

Table 1

In the case of hardened ice or snow, however, a liquid water film may be produced only at the microscopic surface elevations of ice crystals.

Nature of Slush

In nature, a transition occurs from so-called dry snow, which always contains supercooled liquid water, to wet snow. The familiar ability to form a snow ball, due to the adhesive property of liquid water present, is considered a practical distinguishing mark for wet versus dry when describing snow, but the transition is not instant or unequivocal. Increasing the proportion of liquid water at the freezing-point temperature gradually produces slush.

When liquid water exceeds two-thirds of the runway cover by weight, the viscous properties quickly approach those of water. In a mixture containing less than 25 percent ice particles in water, the cover cannot be reported as slush any more.

In daylight and from the air, snow cover on a runway looks white. To be more exact, however, there are gray tones because reflected light is scattered back to the observer from the ice particles within the snow layer and from the air between the particles. When the pores and cavities in the snow are occupied by liquid, light reaches and is absorbed by the relatively dark pavement, making the layer of slush appear darker than snow when viewed from above. When more than about one-third of the snow by weight consists of liquid water, the relative whiteness of snow changes to a dark gray mass. From the air under poor light or visibility conditions, a slush cover on a runway may be difficult to detect. If the ambient light and visibility are suitable, a transition toward darker gray may indicate a change in the runway cover from snow to slush.

Rolling Resistance

The resistance met by a rolling wheel on an aircraft landing gear has several components relevant to a slush-contaminated runway:

- Some rolling resistance is due to, and increases with, dampening of vibrations by the tire material and the tire's deformation, and with speed due to the formation of waves on the tire's circumference. When the rolling resistance increases sufficiently, sliding and eventually skidding inevitably occur, and the temperature of the tire increases;[4]
- Some rolling resistance is flood resistance, dependent on the contaminant volume displaced over time. Viscosity, the proportion of liquid water in slush and the geometry of the ice particles become essential variables that affect skidding/aquaplaning if the tires do not penetrate to the paved surface;
- When the aircraft is turning, some rolling resistance is generated by friction, which increases as acceleration and speed increase;
- Some rolling resistance is generated by the roughness of the contaminated runway, which induces greater vibration in tires than a contaminant-free runway and raises the tire temperature; and,
- Some rolling resistance arises from the friction in wheel bearings, misalignment of wheels and aerodynamic drag.

Slush Distribution Pattern

Visualizing a tire that does not contact the pavement helps explain the problem pilots may face. A tire moving on the runway toward an observer would show the slush, including sand grains, being pushed aside. Very few sand grains get deposited at the bottom of the slush layer, due mainly to resistance from surrounding ice particles that prevent sinking and partly to the buoyancy of the sand grains. However, sand grains heated by absorbed radiation may cause melting that causes them to sink into the slush layer, just as can occur when they are on top of an ice layer.

Sand grains caught in slush under a tire become enclosed in the compacted solid part of the slush. Water is squeezed out and forms boundary layers both on the side of the tire and on the pavement. These layers effectively prevent adequate braking shear forces between the tire and pavement. Sand grains embedded in a mass of loose wet ice particles are ineffective in increasing friction, except when they create microscopic "bridges" between the tire and the stationary base.

A side view of the same tire would show large quantities of slush accumulating and being pushed like a wedge ahead of the wheel, and the tire sinking into a layer of the compressed or laterally displaced slush. Layers of squeezed liquid water appear in the tire footprint. Due to adhesion, water and some slush stick to parts of the rolling tire as they repeatedly contact the runway and then the air.

Braking conditions improve greatly when the slush is sufficiently pushed away from the tire's footprint for tire-pavement contact, but experience and research show that this may not occur. Moreover, measurements of the depth of slush by airport personnel may be inexact or taken at a site that does not represent the entire runway.

Airplane Braking Coefficients

The theoretical maximum friction coefficient for a tire in motion — that is, deceleration with the minimum amount of slip — rarely is achieved in practice. However, autobrake computations and techniques of manual braking approximate generating the maximum shear forces possible between the tire and pavement. The mean derived airplane braking coefficient on slush is best determined after deceleration to a speed range in which the aircraft can be analyzed like any rolling braked vehicle. For the 737 series, this means after slowing to about 55 kt. During this stage of the landing roll, the thrust reverser is assumed to be in the stowed position, and the tires are assumed to have attained maximum temperature.[5]

Flight data recorded from aircraft sensors, which could have aided observation of the deceleration process on slush, were not available for the Svalbard research. Ideally, the angular velocity of wheels as a function of time would be known. Therefore, as an approximation, the mean deceleration was calculated from the interval of time needed to reduce a given speed by a given amount. To compensate for the inability to directly monitor speed, the following basic assumption was used for every flight: The speed would be about 55 kt 12 seconds after the nosewheel touched down on the runway.

The flight crews probably attempted near-maximum braking for the whole deceleration period, including at speeds greater than 55 kt. Even if the deceleration temporarily achieved were greater than the mean value calculated, however, the derived airplane braking coefficients on slush still would be extremely small.

Data Interpretation

While the Skiddometer friction coefficients represent friction conditions between the measuring wheel and the pavement, based only on one measuring device, derived airplane braking coefficients describe the airplane's total braking including the influences of tires, braking system with antiskid and other factors. The Svalbard research showed that the derived airplane braking coefficients in wet conditions could be only 20 to 30 percent of the Skiddometer friction coefficients.

This research found that Skiddometer friction coefficients overestimated the braking action when slush was the predominant form of water-ice contamination. Therefore, it is likely that landings have been performed when the runway conditions should have been reported to the flight crews as "poor" braking action.

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From the table, this discrepancy is striking for so-called "thawing conditions" — runway-contamination conditions A, B and C on the table, in which slush or liquid water covered sanded ice or compacted snow, and the derived airplane braking coefficients were extremely small. These conditions, along with the condition D exception and conditions G and H, confirm the AIBN's determination that in wet conditions, a spread less than or equal to 3 degrees C correlates with poor braking action.[6]

The exceptions in Table 1, excluding the exception to condition D, show a spread exceeding 3 degrees C while runway conditions A and C, excluding the exception to condition C, show dew point temperatures warmer than the corresponding contaminant temperature. This indicates heat released by the formation of dew, so increased melting should be expected.

Conditions D and E in the table reflect the well-known phenomenon of friction increasing on ice as temperature decreases below the freezing point. Surface temperatures, governed by a net outward radiation of heat, were lower/colder than the adjacent air; the difference was 3.2 degrees C in condition E, for example. At lower temperatures, the structure of the ice aggregates — except for existing liquid water, if any, and any more water generated by melting during contact with a heated tire — explain this phenomenon. The exception to condition D shows that very slippery conditions occurred, most likely due to ice deposits from water vapor. Condition F shows that a runway covered by ice or compacted snow — despite a rather low prevailing temperature — may be slippery because of the polishing effect of wind-blown ice fragments.

When the mean wind velocity exceeds 25 kt — as in condition G — or when wind gusts exceed 35 kt, the density of ice crystal fragments suspended in cold air just above the stationary surface may lift the aircraft wheels. This unusual effect, for which aquaplaning is the best analogy, might be called "nival planing." Condition G notably has the smallest derived airplane braking coefficient — 0.03. The rather small air temperature–frost point spread might be explained by the ice fragments suspended in the air, as well as the low temperatures.

Condition H reflects cases of recent snow on the runway at a rather high temperature when the ice aggregates still contained liquid water. This may contribute to slippery conditions when a lubricating layer becomes established under the pressure and heating of a tire. In condition I — a nominally black dry runway heated by solar radiation — derived airplane braking coefficients were on the order of 0.2, obviously too low as note 2 below explains.

Lessons for Operators

In winter 2007-2008, the Civil Aviation Authority–Norway (CAA–N) advised air traffic controllers to only report current braking conditions to pilots as "good," "medium" or "poor" in the cases of slush, wet ice or wet snow on the runway. The category "medium" covered friction coefficients from 0.3 to 0.4 derived from measured friction levels, however, which spanned conditions considered unacceptable for landing to conditions considered acceptable for landing.[7] Updated guidance was published in mid-2008.[8]

It should become possible soon for flight crews to consider information about contaminant status such as stratification and composition; decisive parameters such as surface temperature and flow of energy, that is, heating and cooling; and significant processes such as condensation, thawing and precipitation (*ASW,* 10/07, p. 24). Meanwhile, frozen-contaminated wet conditions with a spread less than or equal to 3 degrees C always should be considered as poor.

Standardized observations could be based on derived airplane braking coefficients — empirically determined — taking into account factors missing from this research, such as autobrake setting, wind and landing weight. As scientific understanding of takeoff and landing on slush evolves, such types of supplementary information for flight crews one day might be considered essential.

Reinhard Mook, Ph.D., who retired in 2006 as a professor at the University of Tromsø in Norway, is an independent consultant and researcher. He has conducted micrometeorological field work as an independent researcher at Norway's Svalbard Airport Longyear and analyses of slippery runway incidents for the Accident Investigation Board Norway, SAS Scandinavian Airlines and the former Norwegian airline Braathens SAFE.

Knut Lande of AIBN provided comments on the draft article.

Notes

1. The Skiddometer BV11, a continuous friction measurement system designed to be towed behind an airport vehicle, was used in this research; it is manufactured by Patria Vammas of Vammala, Finland.

2. Underestimation resulted from this study's assumptions about flight crew use of *friction-limiting braking* — that either the AUTOBRAKE 3 setting, deceleration at 7.2 ft (2.2 m) per second squared, or the AUTOBRAKE MAX setting, deceleration at 14 ft (4.3 m) per second squared, were selected and that antiskid worked to produce the maximum shear forces possible between tire and pavement. In condition I in Table 1, however, far less braking actually was applied.

3. Lande, K. "Winter Operations and Friction Measurements." In *International Cooperation: From Investigation Site to ICAO, Proceedings of the 38th Annual International Seminar* (Volume 11), International Society of Air Safety Investigators, Aug. 27–30, 2007, Singapore.

4. Hegmon, R.R.; Henry, J.J. "Thermal Analysis of a Skidding Tire." *Wear* (Volume 24) 361–380, 1973.

5. European Aviation Safety Agency (EASA). Notice of Proposed Amendment no. 14/2004, *Draft Decision of the Executive Director of the Agency on Certification Specifications for Large Aeroplanes (CS-25), Operation on Contaminated Runways,* Section 7.3.1 "Default Values." EASA has adopted correlations between measured friction coefficients and derived *default friction values,* which represent the effective braking coefficient of an antiskid-controlled braked wheel/tire. The Svalbard research and AIBN research, however, have not confirmed the EASA values except 0.20 for compacted snow and 0.05 for ice. Wet snow and dry snow have been assigned the same value — 0.17 — by EASA; similarly, standing water and slush have the same value expressed as one equation.

6. Lande.

7. CAA-N. "Friction on Contaminated Runways." Aeronautical Information Circular (AIC– I) 07/06, Nov. 20, 2007.

8. CAA-N. "Friction on Contaminated Runways." AIC-I 03/08, July 3, 2008. Considering operator feedback from winter 2007–2008, the CAA-N has introduced a five-level runway-friction scale correlated with Skiddometer friction coefficients. The CAA-N says that only these levels, not coefficients, will be reported to pilots for determining airplane braking coefficient. The estimated levels reported are *good* for friction coefficients greater than or equal to 0.40; *medium/good* for 0.36–0.39; *medium* for 0.30–0.35; *medium/poor* for 0.26–0.29; and *poor* for less than or equal to 0.25. Extra vigilance is warranted for wet ice, wet snow and slush, however, because the CAA-N does not distinguish between wet and dry conditions on contaminated runways; the reported level — given the Skiddometer's accuracy of plus/minus 0.025 — may cause pilots to overestimate the precision of any airplane braking coefficient; and the relevant International Civil Aviation Organization standard for wet conditions allows the accuracy of runway friction measurements to deviate on the order of plus/minus 0.2.

Missed Assessment

Tired pilots neglected to perform a required review before landing.

BY MARK LACAGNINA

A landing distance assessment based on the rapidly deteriorating weather and runway conditions at Cherry Capital Airport in Traverse City, Michigan, U.S., would have shown the Pinnacle Airlines flight crew that diversion to an alternate airport was necessary. But the crew neglected to perform the assessment and pressed ahead.

No one was hurt in the resulting runway overrun shortly after midnight on April 12, 2007, but the airplane, a Bombardier CRJ200LR, was substantially damaged.

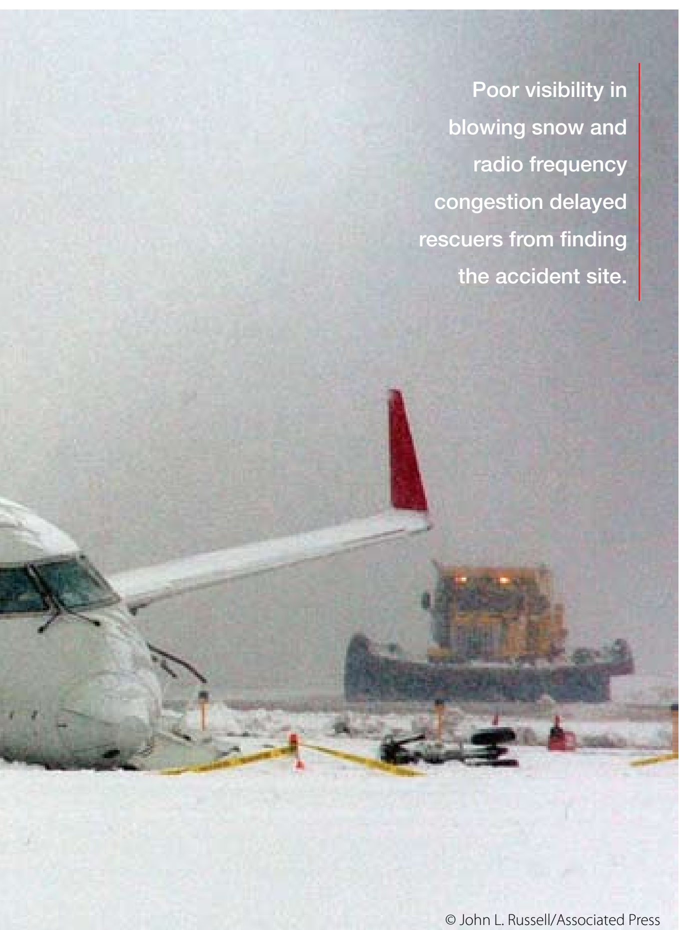
In its final report, the U.S. National Transportation Safety Board (NTSB) said that the probable cause of the accident was "the pilots' decision to land … without performing a landing distance assessment, which was required by company policy." The report said that the omission "likely reflected the effects of fatigue produced by a long, demanding duty day."

The pilots were flying their fifth, and final, leg on the first day of a scheduled four-day trip. The captain, 27, was a flight instructor and contract pilot before being hired by Pinnacle in May 2001. He was upgraded to captain in April 2004 and to line check airman in August 2006. He had 5,600 flight hours, including 4,200 hours in CRJs, with 2,500 hours as captain.

"Company pilots who had flown with the captain described him as professional, knowledgeable, approachable and polite," the report said. "The accident first officer described the captain as a good pilot with strong teaching abilities and a willingness to help."

The captain normally commuted from his home near Pensacola, Florida, to the airline's base in Memphis, Tennessee. "When he was home, his sleep could be interrupted because he tried to provide relief for his wife during the night by responding when his [six-month-old] son awakened," the report said.

The first officer was gaining initial operating experience under the captain's supervision. The captain had tried to find another check airman to do this because he and the first officer were friends. "However, no other check airman was available," the report said. "The captain stated that he attempted to perform the [supervision] with the same strictness he would for any other candidate."



Poor visibility in blowing snow and radio frequency congestion delayed rescuers from finding the accident site.

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The first officer, 28, was a flight instructor and charter pilot before being hired by Pinnacle in January 2007. He completed ground training and a proficiency check in March. He had 2,600 flight hours, including 22 hours in CRJs.

"The first officer was described favorably by two company simulator instructors as a pleasant person and dedicated student with flying skills commensurate with his flight time," the report said. "The accident captain described the first officer as progressing normally toward [initial operating experience] approval, with above-average airplane-handling skills but below-average skills on airplane systems and company procedures."

Long Day

Both pilots were in Minneapolis the night before the accident. The captain awoke at 0700 local time, and the first officer awoke at 0630. They reported for duty at 0900 and performed round-trip flights to Cleveland and to Des Moines, Iowa. Both pilots had lunch between the round-trip flights, but neither had dinner before the flight to Traverse City.

The CRJ, operated as Flight 4712, was scheduled to depart from Minneapolis at 2030. "However, when the pilots arrived at the gate for the accident flight, the gate agent advised them that the flight-release paperwork was not available and that the flight might be canceled," the report said.

Heavy snow, with accumulations of 6 to 8 in (15 to 20 cm), and strong winds were forecast for the northern Great Lakes region. The forecast for Traverse City included winds from 080 degrees at 19 kt, gusting to 30 kt, 2 mi (3,200 m) visibility in blowing snow and an overcast ceiling at 2,500 ft, with temporary conditions of 3/4 mi (1,200 m) visibility and a 500-ft overcast.

The forecast visibility apparently necessitated planning for a landing on Runway 28, the only runway at Traverse City served by an instrument landing system (ILS). About eight minutes before the scheduled departure time, a dispatcher told the captain that the flight could not be dispatched because the tailwind component would exceed the CRJ's 10-kt limitation.

"However, about 22 minutes later, the dispatcher advised the captain that the flight could be dispatched because a new forecast predicted a smaller tailwind component," the report said. The new forecast called for winds from 050 degrees at 10 kt, gusting to 18 kt, 4 mi (6.4 km) visibility in light, blowing snow and a 2,500-ft overcast, with temporary conditions of 1 mi (1,600 m) visibility and a 1,000-ft overcast.

The CRJ departed from Minneapolis at 2153 with 49 passengers and three crewmembers. The captain was the pilot flying. The departure and en route phases of the flight were routine, but several statements recorded by the cockpit voice recorder (CVR) indicated that the pilots were tired. For example, the captain said, "Aw, I'm tired, dude, just [expletive] worn out." Likewise, the first officer said, "Jeez, I'm tired."

"The captain told investigators that when they were en route to [Traverse City], he realized that it had been a long day and that he was more tired than he had realized before the flight departed," the report said. "The first officer stated that he was a little tired during the accident flight but felt OK."

Snow Squall

The CRJ was on initial descent when a Minneapolis Center controller told the crew that his radar display was showing returns consistent with a snow squall at Traverse City. The airport traffic control tower had closed at 2200. The automated surface observing system (ASOS) broadcast at 0010 advised that surface winds at the airport were from 040 degrees at 7 kt and visibility was 1 1/2 mi (2,400 m) in light snow. This was the last ASOS broadcast that the crew listened to.

After confirming that the crew had the current weather conditions at the airport, the controller issued radar vectors for the ILS approach to Runway 28, which is 6,501 ft (1,982 m) long and 150 ft (46 m) wide, and has a 1,000-ft (305-m) runway end safety area.

Weather conditions began to deteriorate rapidly as the CRJ neared the airport. At 0025, the ASOS recorded 1/2 mi (800 m) visibility in moderate snow and 400 ft vertical visibility. Although the crew did not obtain this information, "ground operations personnel provided the pilots with updated weather and runway surface condition information on several occasions as the airplane neared the airport," the report said.

The airport operations supervisor told the pilots that there were "multiple pieces of [snow-removal] equipment on Runway 28" and that the measured friction coefficient on Runway 28 was "40 plus" with thin, wet snow over patchy, thin ice. Runway friction coefficient — or Mu — values range from 0 to 100, with values of 40 and less indicating reduced aircraft wheel-braking performance and directional control.

At 0032, the airport operations supervisor said that all the snow-removal equipment was off the runway but that snow was "coming down

Snow was piling up rapidly on Runway 28, the threshold of which is at the top of the photo, and braking action was reported as nil.

Bombardier CRJ200LR

The first in Bombardier's line of Canadair Regional Jets, the CRJ100 began service in 1992 and shares the engineering designation CL600-2B19 with the Challenger business jet, on which its design was based. Increases in maximum takeoff weights and fuel capacities resulted in the extended-range (ER) and long-range (LR) versions.

The CRJ200 versions were introduced in 2002 with the same airframe, accommodating 50 passenger seats, and with upgraded General Electric CF34-3B1 engines, flat-rated at 9,220 lb (41 kN) thrust.

The accident airplane, shown above, is a CRJ200LR. Maximum weights are 53,000 lb (24,041 kg) for takeoff and 47,000 lb (21,319 kg) for landing. Normal cruise speed is 0.74 Mach, and maximum range is 1,700 nm (3,148 km).

Source: *Jane's All the World's Aircraft*

pretty good." The captain told the first officer that this comment likely meant that "we probably won't see the runway, so be ready for the missed [approach]."

The airport snow plan required runways to be cleared when snow accumulated more than 1/2 in. At 0036, the airport operations supervisor radioed, "I need to know if [you] guys are going to be landing soon, because … this is filling in pretty quick down here." The captain replied that they were intercepting the final approach course inbound and would be landing in about five minutes.

'Braking Action Nil'

At 0038, the airport operations supervisor said, "I'm going to call braking action nil now, because it's filling in real hard." He told investigators that this braking action report was based on tests he had performed with a ground vehicle on Runway 28.

However, the report said that the pilots, who were monitoring both the airport operations radio frequency and the center frequency, did not hear the braking action report because the airport operations supervisor's transmission was partially blocked by a heading change issued by the controller.

According to ASOS information recorded at 0040, visibility had decreased to 1/4 mi (400 m) in heavy snow. About this time, the captain announced on the common traffic advisory frequency that they were inbound from the final approach fix and told the airport operations supervisor that they were two minutes from landing.

The airport operations supervisor replied, "We're all clear of the runway for you, and, again, braking action is probably nil on the runway."

Pinnacle prohibited its pilots from landing after receiving a nil braking action report, but the term "probably nil" was not definitive and was not standard phraseology for reporting braking action, the report said.

The captain requested clarification: "Are you saying it's nil?"

The airport operations supervisor's reply was more ambiguous than his "probably nil" report: "Haven't been out there to do a field report, and it's been five, 10 minutes, so I don't know what it's doing now."

The captain replied, "OK," and then told the first officer, "He's not reporting it nil, he's like saying it's nil."

The captain then asked the airport operations supervisor for an estimate of the depth of the runway contamination. "I'd say it's probably close to half an inch now," he replied. The captain said, "OK, that's not bad, thank you," and then told the first officer, "We're allowed three inches. If it looks ugly when we're coming in, I'll go around. … Half an inch is nothing." Nevertheless, the captain continued to discuss missed approach details with the first officer and said that a diversion to Detroit might be necessary.

The CRJ was nearing decision height at 0042 when the captain told the first officer that he had the runway in sight. Flight data recorder (FDR) data indicated that the airplane crossed the runway threshold at 148 kt — 6 kt above the calculated landing reference speed — and touched down at 123 kt, with a 3-kt tailwind component, about 2,400 ft (732 m) from the threshold.

"The FDR data showed that the brakes were applied and the spoilers deployed immediately after the airplane touched down, and that the thrust reversers were fully deployed within four seconds after touchdown," the report said.

However, the slippery runway and the crosswind contributed to directional-control difficulties when reverse thrust was selected, and the crew deployed and stowed the thrust reversers twice before the CRJ overran the runway at 45 kt. The nosegear separated, and the airplane came to a stop about 100 ft [30 m] beyond the end of the runway.

"The pilots promptly evaluated the condition of the airplane," the report said. "The captain examined the cabin and checked for passenger/flight attendant injuries while the first officer inspected the outside of the airplane." Based on their observations, the captain decided to keep the passengers aboard the airplane until vehicles arrived to transport them to the terminal.

'Four Times Worse'

A performance study indicated that the CRJ's braking ability on the contaminated runway was "more than four times worse than that of a normal dry runway [and that the airplane] would have required an additional 1,146 ft [349 m] of unobstructed runway to stop," the report said. A runway friction coefficient of 17 was measured soon after the accident.[1]

Four months earlier, Pinnacle had implemented an operations specification requiring flight crews to conduct a landing distance assessment "as close as practicable to the time of arrival consistent with the ability to obtain the most current meteorological and runway conditions considering pilot workload and traffic surveillance but no later than the commencement of the approach procedure or visual approach pattern." It also required that the calculated landing distance "be increased by at least an additional 15 percent for all runway conditions."

The report said that the operations specification was consistent with a safety alert for operators (SAFO 06012) published by the U.S. Federal Aviation Administration (FAA) in response to an NTSB recommendation generated by the investigation of the Southwest Airlines Boeing 737 overrun in Chicago in December 2005 (*ASW*, 2/08, p. 28).

"The pilots had adequate information available to indicate that the runway was contaminated and that a landing distance assessment was required," the report said.

The captain told investigators that he had reviewed Pinnacle's landing distance assessment procedures with the first officer during a previous flight but did not perform an assessment before landing at Traverse City. "He stated that he had landed on snowy runways many times and that he believed the runway conditions were OK based on the contamination depth," the report said. "The captain estimated that … the airplane could be stopped using about 3,500 to 4,500 ft [1,067 to 1,372 m] of the available 6,501-ft-long runway."

Nevertheless, the contaminated-runway landing distance charts in the CRJ flight manual showed that the available runway length was inadequate using prescribed landing technique, including touchdown within 1,500 ft (457 ft) of the threshold and proper use of reverse thrust and wheel brakes.

"This accident reinforces the need for pilots to perform landing distance assessments before every landing," the report said. "The assessment is critical when runway conditions may have changed over the length of the flight, as was the case at [Traverse City]."

In its discussion of the role likely played by fatigue in the CRJ pilots neglecting to perform a landing distance assessment, the report said, "The accident occurred well after midnight at the end of a demanding day during which the pilots had flown 8.35 hours, made five landings, been on duty more than 14 hours, and had been awake more than 16 hours." An additional fatigue-inducing factor for the captain was significantly increased workload because of his responsibilities as a check airman.

"Existing FAA pilot flight and duty time regulations permitted the long and demanding day experienced by the accident pilots," the report said.

Among the actions taken by Pinnacle after the accident were to increase pilot training on landing distance assessments and to revise guidance regarding go-arounds. The airline previously had recommended a go-around if a touchdown could not be made within 3,000 ft (914 m) of the runway threshold or the first third of the runway. This was revised to recommend a go-around if a touchdown cannot be made within 1,500 ft of the threshold.

This article is based on NTSB Accident Report NTSB/AAR-08/02: *Runway Overrun During Landing; Pinnacle Airlines Flight 4712; Bombardier/Canadair Regional Jet CL600-2B19, N8905F; Traverse City, Michigan; April 12, 2007.*

Note

1. After the accident, the Traverse City airport operator revised its snow plan to require that runways be closed to air carrier operations when friction coefficient values of 27 or less are measured, or when nil braking action is reported by pilots or ground operations personnel.

COVERSTORY

Winter of Discontent

PART ONE

Ten years ago, reports about control problems caused by the freezing of water-soaked residues left by anti-icing fluids came to the attention of winter operations planners at airlines worldwide. The phenomenon had caused elevator control tab restrictions and pitch oscillations during two BAe 146 flights operated by Crossair. The parent company, Swiss Airlines, consequently abandoned the common European practice of spraying regional/commuter airplanes — up to five times a day — with heated, water-diluted SAE International Type II or Type IV fluids, which are formulated primarily for anti-icing, keeping airplane surfaces free of frozen contaminants before takeoff, and also are approved for deicing.[1,2]

Fast-forwarding to winter 2008–2009, the same basic one-step deicing/anti-icing method — usually with Type II fluid — is still favored by most European deicing/anti-icing service providers and some airlines because it involves a simple application of various mixtures, holdover times well suited to diverse airport environments with frost more prevalent than ice/snow contaminants, and a relatively low cost.

A number of European companies and organizations exposed to this risk of flight control restriction continue pressing for faster government intervention (*ASW*, 9/06, p. 26), however. They argue that commercially driven decision making, inadequate voluntary compliance with safety advice and a weak regulatory environment on this issue have not fully addressed far-reaching safety recommendations by the U.K. Air Accidents Investigation Branch (AAIB) and the German Federal Bureau of Aircraft Accidents Investigation (BFU), or the risk factors identified in dozens of incidents after the Crossair experience.

The European Regions Airline Association (ERA), the Association of European Airlines, airframe manufacturers and other organizations advocate the regulation of deicing/anti-icing service providers, which are not covered by civil aviation regulations because of their legal status as contractual partners of the operators.[3]

Risks from anti-icing fluid residues remain troublesome for European airlines despite a wealth of safety advice.

BY WAYNE ROSENKRANS

Paste-like gels form when anti-icing fluid residue absorbs water in aerodynamically quiet areas.

"Regulatory action is needed in some areas before a major incident occurs that will subsequently expose inactivity on these known serious issues," said Mike Ambrose, director general of ERA. "There is a strong argument for requiring the regulation of agencies undertaking deicing and anti-icing, thereby ensuring that these agencies maintain proper training and qualification of staff carrying out ground deicing/anti-icing activities. Operations can be safely undertaken when these problems are addressed by appropriate procedures, however, although the associated costs of aircraft checking and cleaning of critical areas are high."

The current situation is seen as a consequence of the gradual shift of regulatory oversight from national civil aviation authorities to the European Aviation Safety Agency (EASA), and it has dissatisfied the advocates of deicing/anti-icing reforms. "Type certificate holders have been extremely frustrated in Europe — there is no single accountable regulatory authority that we can go to and speak to about the whole breadth of the residue issues, such as aircraft design information, providing deicing/anti-icing service, maintenance instructions, fluid specifications and operation of aircraft," said Alistair Scott, chief airworthiness engineer and head of flight safety for BAE Systems Regional Aircraft, the type certificate holder for the BAe 146/Avro RJ. "Due to the evolving regulatory environment, people don't feel the need to take action on all these issues."

In September 2008, EASA published an update of its general policy and action plan covering short-term and long-term solutions, including responses to public comments about which of several proposed countermeasures should be pursued.[4]

"Dried fluid residue could occur when surfaces have been treated but the aircraft has not subsequently been flown and not been subject to precipitation," says EASA's latest advisory information. "Repetitive application of thickened deicing/anti-icing fluids may lead to the subsequent formation/buildup of a dried residue in aerodynamically quiet areas, such as cavities and gaps. This residue may rehydrate [absorb water] if exposed to high humidity conditions, precipitation, washing, etc., and increase to many times its original size/volume [often described as a wallpaper paste–like gel].

"This residue will freeze if exposed to conditions at or below 0 degrees C [32 degrees F]. This may cause moving parts such as elevators, ailerons and flap actuating mechanisms to stiffen or jam in flight. Rehydrated residues may also form on exterior surfaces, which can reduce lift, and increase drag and stall speed. Rehydrated residues may also collect inside control surface structures and cause clogging of drain holes or imbalances to flight controls. Residues may also collect in hidden areas around flight control hinges, pulleys, and grommets, on cables and in gaps."[5]

EASA recommends consideration of the two-step deicing/anti-icing method — in which deicing with Type I fluid helps to remove residue — if thickened fluids are to be used, residue inspection/cleaning procedures under operator policies that define safe intervals, situations necessitating supplementary training, and operators obtaining information from fluid manufacturers to be able to specify, to the extent possible, brand name fluids with the lowest gel-formation potential from residues.

For the short term, EASA will focus on requiring type certificate holders/manufacturers to inform operators about preventive actions and provide instructions to operators on detecting and removing dried residues and rehydrated gel, and requiring operators to implement these instructions.

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Regional safety officials eventually will be empowered to take actions they deem necessary on more of the residue issues raised by the deicing/anti-icing reform advocates. "In the meantime, responsibilities remain with the appropriate bodies within the member states, who, according to the agency's preliminary research, generally do not regulate this area," EASA said.

"The greatest risk to flight safety is still a control restriction that can't be cleared in flight," said Scott. "We were pleasantly surprised in winter 2007–2008 by the majority of BAe 146 operators following current safety advice. They ended up with a very small number of incidents — a handful compared with two or three years ago — albeit at significant cost due to their cleaning and inspection routines. The four main countermeasures are cleaning and inspections, training, better fluids and use of Type I fluids when possible. The only way we are ever going to fix this situation is by putting in place a new generation of fluids. All these factors are being tackled concurrently, but progress is slow. Some European operators have learned nothing and, in fact, have taken a step backward."

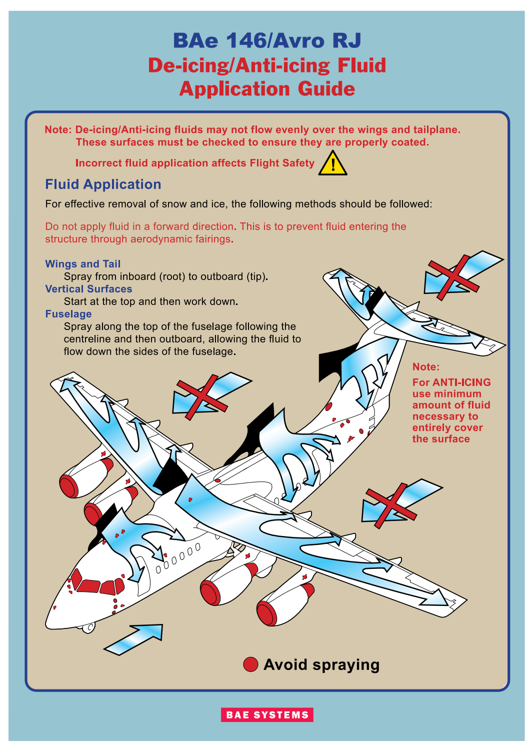
"The four main countermeasures are cleaning and inspections, training, better fluids and use of Type I fluids when possible."

Serious Incidents

In early incident reports involving the 146/RJ, the McDonnell Douglas DC-9/MD-80 and the de Havilland Canada DHC-8, the common denominators were non-hydraulically powered flight control systems, for which flight crews may lack sufficient physical force to break out frozen deposits; high T-tails difficult to inspect for residues; and short-haul operations with multiple fluid applications per day, said Kirsten Dyer, chairwoman of the SAE G12 Committee's Residue Workgroup and senior materials engineer for BAE Systems Regional Aircraft. Civil aviation authorities initially responded by advising operators not to use the Type IV fluids on aircraft with non-powered flight controls.

Often-cited cases of control restrictions (*ASW*, 2/07, p. 58) include one in March 2003 near Edinburgh, Scotland. The flight crew of a DHC-8 saw that the autopilot had failed to level the airplane at the selected altitude of Flight Level 170. The combined efforts of both pilots to stop the climb were ineffective. They conducted memorized actions for an elevator jam condition and, by selecting the pitch disconnect handle, were able to regain elevator control with reduced elevator authority. After conducting quick reference handbook procedures, they landed the airplane without further incident. The cause was restriction of the right elevator spring tab by frozen rehydrated residues of anti-icing fluids from previous fluid applications.[6]

"Between January and April 2005, and mainly over a four-day period, 48 incidents were reported on RJ/146, Embraer 145 and DHC-8 aircraft, directly related to anti-icing fluid residues," Dyer said. Although the AAIB and BFU have



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published tables of apparent incidents, a reasonably consistent and up-to-date count of all European incidents has yet to be published by any authority to the knowledge of Dyer and Scott.

A review of winter 2007–2008 operator data by the residue workgroup has been inconclusive regarding any new causal factors. "There doesn't seem to be any pattern, rhyme or reason as to why an incident occurs on one aircraft and doesn't on another of the same type," Dyer said. "For instance, cleaning programs of some operators allow only so many applications of any anti-icing fluid before calling for a residue inspection. But one had an incident about two or three fluid applications before reaching its interval limit. This operator's other airplanes of the same type, with the same fluids applied in the same conditions, did not show any residue on inspection when they reached the same limit."

Dried residue in the form of light powder or rubbery skin remains after the evaporation of glycol and water from the Type II, Type III and Type IV fluids but, by itself, is relatively harmless until unusual sequences of weather conditions occur, Scott said. During internal residue inspections, maintenance technicians usually can see the gel, but residues are difficult to detect except by intentionally spraying water onto suspected areas in a heated hangar, then waiting 15 minutes to see if the gel forms.[7]

"As the fluids dry out in layers, incidents have occurred after the top layers of the residue have been rehydrated and cleaned off, and the aircraft has then been returned to service, with the inner layers still rehydrating from contact with the cleaning water, which are then freezing in flight," Dyer said.[8] "A danger in relying on inspection and cleaning programs is that they are open to errors and changes in fluid. For instance, one European operator's program worked through the worst recent conditions — winter 2004–2005 — but after changing to a new product the next season, the operator had a series of incidents."

Some manufacturers of commercial transport airplanes with hydraulically powered flight control systems, such as Boeing Commercial Airplanes, say that any airplane type could be susceptible to adverse effects from frozen residues; Boeing provides type-specific safety advice to operators.[9]

Any time they apply anti-icing fluid, airlines actually are using one contaminant to remove another, the frozen contaminant, Scott said. "Effectively, they then take on the commitment that they subsequently will remove this fluid, including the residues, at safe intervals to keep the aircraft airworthy," he said. "The whole winter operation is a balance of risks and defenses; getting the balance right keeps the operators on the safe side."

Dyer says that significant reduction of the known residue-related risks ultimately will require "airframe manufacturers to modify their current and future aircraft types if possible [such as by improved seals to prevent fluids from penetrating aerodynamically quiet areas]; service providers and airlines to ensure the widespread availability and use of Type I fluids and the two-step process; fluid manufacturers to develop fluids that have acceptable residue properties; SAE International to [update] the SAE AMS 1428 specification such that only fluids demonstrating suitable residue properties can be approved in the future, as well as giving proper guidance on their application; and in particular, regulatory authorities to put the correct measures in place to ensure that the above processes are implemented."[10]

Part Two will cover industry attempts to study the gel-formation potential of anti-icing fluids in the laboratory and report test results; overcome barriers of proprietary information; require practices that lead to consistent results; and seek new fluids that meet goals for safety, effectiveness, the environment and cost.

Notes

1. Beisswenger, Arlene; Perron, Jean. "Laboratory Testing of Aircraft Anti-Icing Fluid Rehydrated Gel Residues." Paper presented to the SAE Aircraft and Engine Icing International Conference, Seville, Spain, Sept. 24–27, 2007.
2. EASA. "Ground De-/Anti-Icing of Aeroplanes: Intake/Fan-blade Icing and Effects of Fluid Residues on Flight Controls." Safety Information Notice (SIN) no. 2008-29, April 4, 2008. EASA said, "Type II and Type IV [anti-icing] fluids contain thickeners which enable the fluid to form a thicker liquid-wetting film on surfaces to which it is applied. Generally, this fluid provides a longer holdover time than Type I [deicing] fluids in similar conditions. … Type III [is a] thickened [anti-icing] fluid intended especially for use on airplanes with low rotation speeds."
3. BFU. "British Aerospace BAE-146 – De-icing Fluid." Report no. 5X007-0/05.
4. EASA. "Comment Response Document to Advance Notice of Proposed Amendment (NPA) 200711 on Possible Course of Action for EASA to Address the Residues That Can Result From Application of Deicing/Anti-icing Fluids." Sept. 2, 2008.
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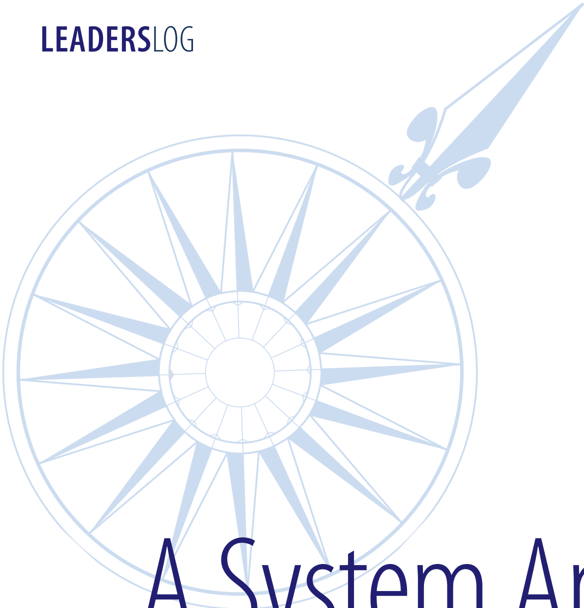

BY IGOR LEVITIN

A System Approach to Safety

The state flight safety program being implemented in the Russian Federation addresses common problems in international civil aviation.

In tackling flight safety problems in the Russian Federation, we must take into account the rapid growth of air traffic, the renovation of the fleet and the development of a new generation of aviation experts.

The International Civil Aviation Organization (ICAO) has said that, in light of these trends, the most efficient way to enhance flight safety is to implement a system approach to flight safety management. As a result, ICAO adopted changes in its international standards, telling states that it is up to them to establish an acceptable level of safety and to develop state flight safety programs.

The state flight safety program being implemented in the Russian Federation addresses common problems in international civil aviation and includes proposals for research and development that would enable a switch to higher standards for personnel training and aircraft operations. Preliminary estimates are that the program could cut the accident rate at least in half.

The civil aviation authority is working with operators, airports, aircraft and equipment manufacturers, maintenance organizations and air traffic control (ATC) units to achieve a minimum acceptable goal — an acceptable flight safety level.

To reach this goal, we must complete the following tasks:

- Establish a flight safety management system in the Russian Federation;
- Develop modern requirements in the field of aircraft, airport and air traffic services (ATS), and aviation personnel training;
- Provide for a systems approach for determination of the causes of dangerous situations and risk factor control to minimize fatalities and damage, including financial, ecological and social losses; and,
- Harmonize the distribution of responsibility and accountability between the state and operators, airports, aircraft and equipment manufacturers, maintenance organizations and ATC units.

The program sets forth the order in which the tasks should be addressed.

First, in 2008–2015, interagency procedures will be established to consider flight safety issues, federal and industry programs will be set up to meet the obligations, and provisions will be made for agency and interagency actions to enhance flight safety.

Second, beginning in 2009, long-term arrangements will be implemented to establish the flight safety program. The arrangements will include the development of rules and regulations, including those that will deal with implementation of international standards in aircraft operations; rules of the air, including assessment of airworthiness and maintenance standards pertaining to aircraft and equipment; ATC systems in airlines; maintenance organizations; airports; and ATS units.

We will encourage consolidation and coordination among agencies and organizations that provide for civil aviation safety and develop a legal tool for interagency consideration of flight safety issues. This coordinated approach will be based in part on the implementation of the civil aviation safety control system; monitoring advances in technology and industry best practices to enhance the efficiency of the state aviation system; creating a database to include information on personnel licensing, aircraft airworthiness, certification of aviation enterprises, violations of the Air Code of the Russian Federation, accidents and incidents; analyzing trends, including information on accidents and incidents, and assessments of compliance with the Air Code and international flight safety requirements; and disseminating safety materials and holding workshops and conferences.

Russia uses contemporary international standards of flight crew training to help reduce the impact of human factors on flight safety. To ensure the quality of training, we use modern integrated simulators to instruct both flight crews and air traffic controllers on how to react to emergencies and to monitor their in-flight behavior.

A federal program, scheduled for 2010–2015, to develop Russia's transport system will be supplemented by long-term flight safety proposals. At the same time, new federal aviation regulations will be introduced for aviation personnel training and licensing. Other elements of the program call for the training of state inspectors who will oversee operations and airworthiness.

To reduce human factors–related accidents, we must renovate our fleet and provide modern aviation technology. The Law of the Air will include measures to equip aircraft with modern flight data recorders, air-to-air and air-to-ground proximity warning systems, and accurate navigation systems. To meet requirements aimed at maintaining the airworthiness of the existing fleet, aircraft manufacturers will continuously monitor aircraft operation processes to be able to eliminate dangerous factors and improve oversight activities in civil aviation.

The program also provides for the technical renovation of ground infrastructure and the creation of conditions to make the operation of modern aircraft more efficient, such as implementation of reduced vertical separation minimum (RVSM) airspace and improvement of meteorological services.

In addition, we have developed measures to improve aviation medical services, including updating medical documents, upgrading preflight checks of aviation personnel and developing rehabilitation procedures to maintain health, fitness and professional longevity.

Scientific studies are needed to evaluate the effectiveness of flight safety efforts and the role of human factors, aviation technology and other initiatives.

The program stipulates flight safety procedures to control the establishment and modernization of the air navigation system and to mitigate risk factors. These procedures are to be carried out

Igor Levitin is transport minister of the Russian Federation.

beginning with development and design of the air navigation system and continuing through its certification, implementation and operation.

The procedures apply to all parts of the air navigation system, as well as to supporting organizations, and call for development of interdependent flight safety indices for different flight stages and different segments of the air navigation system, definition of their acceptable task levels and assessment of quantitative values of these indices and trends.

Among other things, the procedures also call for elaboration of scientific methods to enhance flight safety for air navigation purposes based on a flight safety related risks model; implementation of advanced technical and organizational approaches approved by ICAO and based on a scientific approach to flight safety provisions and management, including RVSM and joint air navigation service areas; and improvements in the professional training of engineers, technicians and ATC officers in charge of air navigation services, including inspectors.

Other provisions involve upgrading aviation safety requirements with respect to the new responsibilities of air traffic management organizations and improving interaction with air navigation service subsystems, including search and rescue and meteorological offices.

Implementation of the program depends on further improvement of state regulatory authorities, airspace users, aircraft owners, civil aircraft and equipment manufacturers, aviation enterprises, airports, maintenance and air traffic management organizations, in accordance with the legislative and international obligations of the Russian Federation.

The program evaluation process will be based on the work of the Interagency Civil Aviation Flight Safety Commission, taking into account critical elements of the State Safety Oversight System, stipulated by ICAO.

The program should, within the next three to five years, result in stabilization of the level of flight safety and serve as a prerequisite for enhanced flight safety and increased air traffic.

Defensible Analysis

BY WAYNE ROSENKRANS

Australian accident investigation framework demonstrates strong standard of proof for determining safety factors worldwide.

Efforts to harness advanced safety concepts, information technology and investigator training in aviation accident investigations sometimes have sparked controversy for the Australian Transport Safety Bureau (ATSB). Critics of the innovations found fault last year with the bureau's investigative analysis framework in the context of its first major safety investigation — the May 2005 fatal crash of a Fairchild Metro 23 near Lockhart River in Queensland (*ASW*, 6/07, p. 29).[1]

The Civil Aviation Safety Authority of Australia (CASA), for example, took exception to the framework's *ATSB investigation analysis model* and its standard of proof for determining whether something contributed to an accident. Two independent assessments — by the head of a government review and a state coroner[2,3] — later concluded, however, that most of this criticism was unwarranted, and commended the bureau for implementing comprehensive changes.

This year, a report by Kym Bills, the ATSB's executive director, and Michael Walker, a senior transport safety investigator, explained why the bureau began to develop this "enhanced and more transparent" framework in 2004 and how it works, and invited professionals in the global safety investigation field to consider important safety issues they encountered.[4] The framework introduced substantial changes of terminology; the investigation analysis model, an ATSB adaptation of the Reason model;[5] requirements for all investigators to adhere to a defined analysis process, called the *workflow;* and investigator training on the corresponding policies, guidelines and investigative tools.

"The ultimate aims of the … framework [are] to improve the rigor, consistency and defensibility of investigation analysis activities, and improve the ability of investigators to identify safety issues in the transportation system," the report said.

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The framework was developed in conjunction with replacing an outdated accident/incident database with a software suite, the ATSB Safety Investigation Information Management System, which was launched in April 2007.[6] "A key component is a set of tools for the analysis phase of a safety investigation," the report said.

In an article last year for Flight Safety Foundation, Bills noted the new system's environment and the bureau's pursuit of a more disciplined approach and professional consistency (*ASW*, 9/07, p. 32). He said, "There are new and unusual twists in safety improvements based on different organizational cultures and pressures, regulatory environments and interfaces with other humans and changing systems and technologies." Investigative bodies find the analysis aspect of their work among the most difficult tasks, with complex crash scenarios likely to involve missing, obscure or even deceptive data, the report said.

The current framework brings to the table a higher standard of proof than has been used in Australian coroner inquests — which have influenced the ATSB analytical advances — or civil legal proceedings (Table 1). This statement applies to "factors relatively close in proximity to the occurrence (that is, more than 66 percent [likelihood] versus more than 50 percent)," the report said. "But as an ATSB safety investigation proceeds to identify contributing safety factors more remote from the occurrence, the degree of relationship of the factors to the occurrence itself will generally decrease using the ATSB framework."

Like many independent investigative bodies, the ATSB cannot compel other entities to implement safety recommendations, called *safety actions* in the framework; rather, the method of influencing safety is through reports and other communication, which require "a rigorous analysis process and compelling arguments" to be effective, the report said. The ATSB therefore set out to create a defined analysis process to improve the quality of analysis, to raise credibility and increase the likelihood of safety actions being adopted by government and/or the industry. Analytical frameworks and safety investigation methods of other safety investigation organizations were reviewed, but none met the ATSB's needs, the report said.

The review for the country's minister for infrastructure, transport, regional development and local government on improving some aspects of the functional relationships of ATSB and CASA in 2007

Influential Inquest Findings by Australian Coroners About Aircraft Accidents

Accident Date	Coroner Jurisdiction	Accident Aircraft	Relevance to ATSB Investigative Analysis Framework
May 7, 2005	Queensland	Fairchild Metro 23	The coroner commended the ATSB framework with a few exceptions.[1]
A transport ministry review said that at the inquest after release of the ATSB's final report, "CASA lawyers sought to attack the ATSB's investigation methodology, alleging unintentional bias." The bias allegedly was emphasis on organizational influences, and the ATSB's findings were said to be presented in a distorted, unbalanced and unfair manner. The coroner commented that neither the investigation framework nor the ATSB investigation analysis model were biased, but questioned why the ATSB equated the word *probably* to 66 percent or greater probability when analyzing human behavior as a contributing safety factor. The coroner also said that issues of high relevance and low relevance should not need the same level of proof in identifying safety factors/issues.			
July 28, 2004	New South Wales	Piper PA-31T Cheyenne	The ATSB final report did not cover possible reclassification of airspace.
The aviation industry perceived that the ATSB missed an opportunity to analyze how the adoption of one type of airspace used in the United States could have influenced the outcome, the review said.			
Aug. 11, 2003	Western Australia	Cessna 404	The ATSB final report did not mention any CASA oversight issues.
The coroner's comments and safety recommendations identified CASA oversight deficiencies. A CASA witness at the inquest dismissed the ATSB's findings and raised previously unmentioned, safety-relevant issues, the review said.			
Sept. 26, 2002	Queensland	Piper Cherokee Six	Testimony after the ATSB final report raised additional issues and concerns.
At the inquest after release of the ATSB's final report, CASA raised significant issues about the ATSB's investigation and provided evidence that differed from what its witness had provided during the ATSB safety investigation, according to the ATSB.			

ATSB = Australian Transport Safety Bureau; CASA = Civil Aviation Safety Authority of Australia

Note

1. The Office of the State Coroner, Queensland, cited Flight Safety Foundation publications on approach and landing accident reduction, including those involving controlled flight into terrain, in its findings and comments.

Sources: ATSB; *ATSB/CASA Review 2007*; Office of the State Coroner, Queensland

Table 1

likewise noted, "The selectiveness with which the ATSB chooses accidents and incidents to investigate, the quality of its analysis and conclusions, and the quality and practicality of the reports and safety recommendations it produces have a direct influence on the value of its contribution to the Australian aviation system."

The ATSB was dissatisfied, however, with the slow pace globally of analytical advances. "Despite its importance, complexity and reliance on investigators' judgments, analysis has been a neglected area in terms of standards, guidance and training of investigators in most organizations that conduct safety investigations," the ATSB report said. "Many investigators (from most safety investigation organizations) seem to conduct analysis activities primarily using experience and intuition which are not based on, or guided by, a structured process. It also appears that much of the analysis is typically conducted while the investigation report is being written. As a result, the writing process can become inefficient, supporting arguments for findings may be weak or not clearly presented, and important factors can be missed."

To overcome this, the ATSB framework provides guidance in the form of functional questions, criteria, tables, lists and forms. For example, testing the influence of a potential safety factor requires the investigation team to account for the factor's relative timing, reversibility, relative location, magnitude, plausibility, past influence, enhancers, inhibitors, characteristics as a problem, required assumptions, alternative explanations for the problem and directionality of influence.

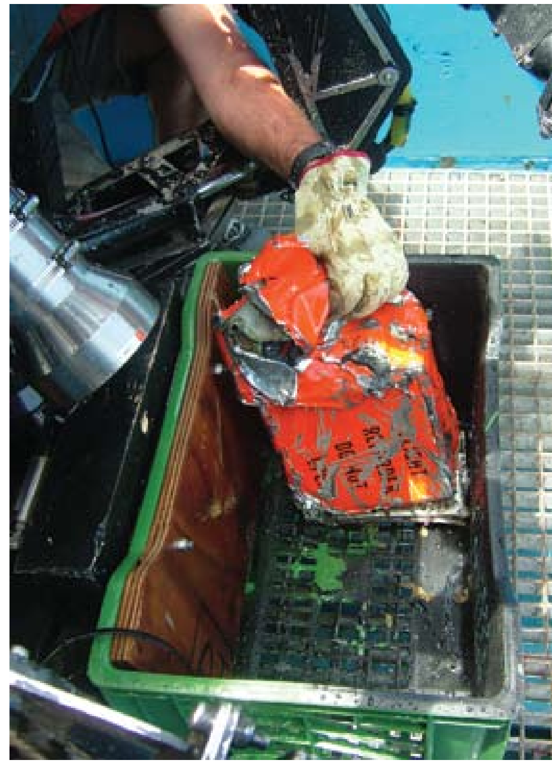
The sequential phases of a safety investigation under the framework are preliminary analysis, safety factors analysis, risk analysis, safety action development and analysis review. "[The risk analysis] phase involves reviewing and evaluating the available data, and converting it into a series of arguments to produce a series of relevant findings," the report said.

For the purpose of identifying *safety factors* — similar to the term *causal factors* in some countries — *contributing safety factors* and *critical, significant or minor safety issues,* the safety factors analysis and risk analysis phases are considered critical because of their relationship to the accuracy and completeness of findings, and to identifying effective safety actions. Careful logical reasoning becomes a key to the defensibility of findings.

"Some aspects of the technical or engineering side of an investigation involve deductive reasoning [with findings derived from premises with logical certainty], particularly when reaching intermediate findings," the report said. "However, the majority of the reasoning conducted in safety investigation involves inductive arguments [with findings expressed with some level of probability but not certainty], particularly when discussing safety factors. This applies to operational, technical and engineering aspects as well as human and organizational aspects."

The framework requires, from the preliminary analysis onward, that investigators ask a set of prepared generic questions, then ask a set of prepared focused questions designed to elicit logical explanations. Some aspects of an accident then may require the investigator to apply experience-based techniques that probe more deeply into some potential safety factors.

"Substantially more emphasis" also goes to its analysis review phase under the framework, the report said. Here, every safety factor identified earlier is subjected to a separate logical test of its existence, influence and importance. A potential safety factor may remain in the final report, be reclassified or be dropped as of "no consequence to the investigation" at this phase.



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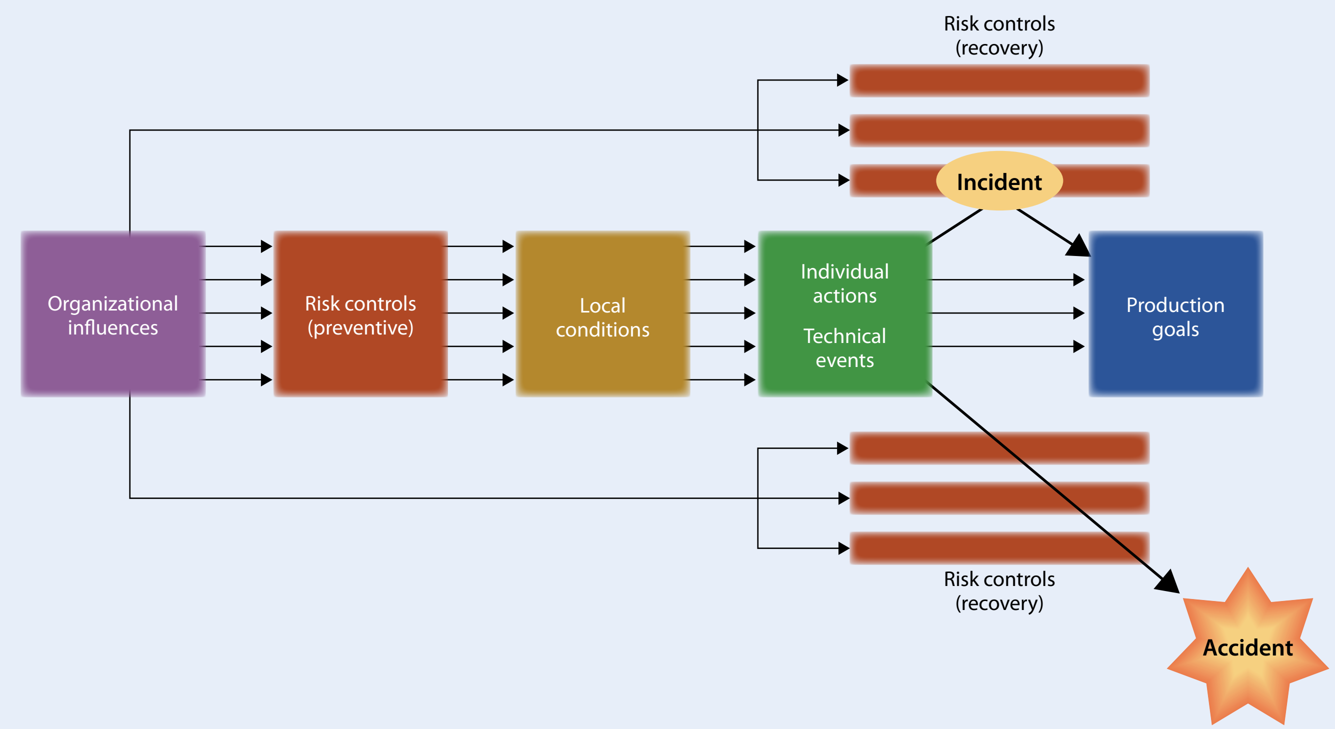
Reason Revisited

The International Society of Air Safety Investigators in recent years has facilitated discussions of the extent to which the accident development model adopted by investigators affects fair/balanced consideration of organizational factors/latent conditions versus individual factors/active errors.

The ATSB's adaptation of the Reason model generated part of the criticism from the outset, but the bureau intended its version to inherently correct for biases.[7] For instance, the adapted model is only one element of a comprehensive process to help identify potential safety factors. "Before any findings are made about whether these potential [organizational] factors contributed to the development of the occurrence, or were otherwise

ATSB Adaptation of the Reason Model



ATSB = Australian Transport Safety Bureau

Note: The Reason model incorporates theories of accident causality by James Reason, a psychologist.

Source: ATSB

Figure 1

important, they need to be tested or verified," the report said. "In the ATSB analysis framework, this involves using a structured process to examine the available evidence and conducting tests for existence, influence and importance."

The adapted model (Figure 1) essentially helps to create a common mental picture of where preventive risk controls and recovery risk controls fit into the normal process of obtaining the production goals, safe flights. During a safety investigation, however, the investigators begin on a simplified vertical version of the chart at the accident/occurrence event label, which includes any technical problems, then work backward through individual actions and technical events, local conditions, preventive risk controls and, finally, organizational influences.

Notes

1. ATSB. "Collision With Terrain, 11 km NW Lockhart River Aerodrome, 7 May 2005, VH-TFU, SA227-DC (Metro 23)." Report 200501977. April 4, 2007.
2. *ATSB/CASA Review 2007: Report to the Minister for Infrastructure, Transport, Regional Development and Local Government.* Dec. 21, 2007.
3. Barnes, Michael. Office of the State Coroner, Brisbane, Queensland, Australia. "Inquest into the Aircraft Crash at Lockhart River." Aug. 17, 2007.
4. Walker, Michael B.; Bills, Kym M. "Analysis, Causality and Proof in Safety Investigations." ATSB Transport Safety Report, Aviation Research and Analysis Report AR-2007-053. March 11, 2008.
5. Reason, J.; Hollnagel, E.; Paries, J. "Revisiting the 'Swiss Cheese' Model of Accidents." EEC Note 13/06, Eurocontrol Experimental Centre, 2006. In 1990, psychologist James Reason, a professor at the University of Manchester, England, proposed a model of accidents resulting from interactions between "real time 'unsafe acts'" by front line personnel and latent conditions.
6. *ATSB/CASA Review 2007.*
7. In response to criticism, the ATSB report said that investigators typically express verbally what they mean and use the word *probably* in discussing whether something is a contributing safety factor. This word corresponds with greater than 66 percent likelihood on a widely adopted scale devised by the Intergovernmental Panel on Climate Change.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The Science of

Regulators see a larger role for non-traditional methods of mitigating pilot fatigue and preventing fatigue-related accidents.

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Moving toward a systems approach to preventing fatigue in aviation operations, the U.S. Federal Aviation Administration (FAA) says that, like other civil aviation authorities, it is going beyond traditional programs that limit the number of hours worked in favor of more comprehensive plans to help operators identify fatigue and mitigate its risks.

"While fatigue may not have been called out by name, it's been … lurking in many of the accidents we've faced over the years," Acting FAA Administrator Robert A. Sturgell told a fatigue safety forum convened by the agency in June to consider "new ways to manage fatigue."[1]

The FAA characterized the safety forum as an early step in its development of a new approach to handling fatigue and its revision of existing policies, which have been in effect with relatively few changes for 50 years.

"Even with an outstanding safety record, we're not where we need to be when it comes to understanding and dealing with fatigue," Sturgell said.

The solution is not necessarily "adopting prescriptive criteria for fatigue risk abatement," he said, adding, "We need to address all levels of fatigue and put appropriate mitigations in place — mitigations that are proportionate to the risk."

Plans call for the proceedings of the symposium to be published in late 2008 in an effort to widely disseminate information about fatigue and fatigue mitigation.

The FAA's plans — outlined in August, in response to safety recommendations by the U.S. National Transportation Safety Board (NTSB) — are to "educate the industry on the reality of fatigue and ways to effectively mitigate its dangers." The FAA said it would first develop guidance for fatigue management in ultra-long-range (ULR) operations — flights longer than 16 hours — and then apply that guidance to other flight profiles.

ULR fatigue-management guidance currently exists in the form of recommended guidelines published in 2005 by the ULR Crew Alertness Initiative, sponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.[2]

In addition, the FAA said that data gathering will continue on the fatigue aspects of ULR flights and other flight operations, and that the new data will be essential in the development of fatigue guidance documents and standardized protocols for data gathering.

Fatigue

BY LINDA WERFELMAN

These standardized protocols will provide "reliable tools to validate air operators' fatigue management actions and also will give solid basis for policy guidance to the industry," the FAA said.

The NTSB recommendations, issued after investigations of several recent fatigue-related accidents and incidents — including a Pinnacle Airlines Bombardier CRJ200LR runway overrun at Traverse City, Michigan, on April 12, 2007 (see p. 20) — called on the FAA to "develop guidance, based on empirical and scientific evidence, for operators to establish fatigue management systems" and to "develop and use a methodology that will continually assess the effectiveness of fatigue management systems[3] implemented by operators, including their ability to improve sleep and alertness, mitigate performance errors and prevent accidents and incidents" (see "Recent Fatigue-Related Events," p. 41).

The NTSB defines fatigue management systems as incorporating various fatigue-management strategies, including scheduling practices, attendance policies, education, medical screening and treatment, "personal responsibility

A preliminary incident report says a Go! Bombardier CL-600 flew past its destination airport in Hilo, Hawaii, U.S., because the flight crew fell asleep.

during non-work periods," task/workload issues, rest environments, commuting policies, and/or napping policies.

According to the NTSB recommendations, the new guidance would supplement flight- and duty-time regulations — not replace them.

"Although scheduling practices and flight- and duty-time limits still need to be addressed, the [recent fatigue-related accidents and incidents] have clearly shown that other issues contribute to human fatigue in aircraft operations and that a comprehensive approach that includes company policies and crewmember responsibilities is needed to effectively mitigate the hazards posed by fatigue in the aviation environment," the NTSB said in a letter conveying its safety recommendations to the FAA.[4]

The fatigue management system concept already is in place in several civil aviation authorities, including New Zealand, where regulations were implemented in 1995 to require air carriers to either comply with traditional flight- and duty-time limitations or with a fatigue management system approved by the Civil Aviation Authority. The regulation establishes maximum monthly and yearly flight hours for flight crewmembers and specifies that operators must not allow crewmembers to fly if their condition could present a risk to flight safety.

In addition, the International Civil Aviation Organization (ICAO) is developing a document that will discuss fatigue management systems and will prescribe them as an alternative to flight- and duty-time limits.

Fatigue risk management systems (FRMS) also are in place in some airlines.

One of the first airlines to adopt an FRMS was easyJet, which began the system as a research program to gather data on pilots' sleep and fatigue-related performance. The research effort led to revised work schedules, continuing data collection and research on fatigue risks, a procedure for crewmembers to report fatigue within a just culture, and a process for investigating the role of fatigue in all incidents.[5]

Often, an FRMS is one element of an airline's safety management system (SMS), and many of the FRMS components — such as a just safety culture and non-punitive safety reporting — are also integral parts of an SMS. This is the approach taken by Transport Canada (TC), which has published a series of reports on how a fatigue management system should be implemented and why.[6]

"Managing fatigue-related risk under an SMS framework involves developing comprehensive defenses against the hazard of fatigue based on a formal assessment of risk," TC says. "Organizations can decide to do as much or as little as necessary to manage their own levels of risk. … An effective … fatigue risk management system should use multiple, overlapping and redundant defenses against a given hazard.

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U.K. Air Accidents Investigation Branch

Fatigue was identified as a factor in the crash of a Jetstream 32 in Kirksville, Missouri, U.S., top photo, and may have affected a TNT Airways Boeing 737-300 crew in a June 15, 2006, accident at England's Nottingham East Midlands Airport. No one was hurt in the accident, in which the right main landing gear separated from the airplane.

Recent Fatigue-Related Events

Among the recent accidents and incidents cited by the U.S. National Transportation Safety Board (NTSB) as examples that highlight the risks of human fatigue in airline operations are the following:[1]

Feb. 13, 2008 — An incident in which a Go! Bombardier CL-600 en route from Honolulu to Hilo, Hawaii, flew past the destination airport while still in cruise flight. Air traffic control (ATC) tried repeatedly to contact the crew but received no response for 18 minutes as the airplane, operated by Mesa Airlines, flew 26 nm (48 km) past Hilo. Then the crew contacted ATC, complied with instructions for their return to Hilo and safely landed the airplane. The three flight crewmembers and 40 passengers deplaned safely.

A preliminary investigation found that "both pilots unintentionally fell asleep during cruise flight," the NTSB said in a safety recommendation letter to the U.S. Federal Aviation Administration (FAA). Although the crew had been on duty less than 4.5 hours when the incident occurred, "the pilots were on the third day of a trip schedule that involved repeated early start times and demanding sequences of numerous short flight segments," the NTSB said. In addition, the NTSB said, one pilot was diagnosed after the incident with obstructive sleep apnea, which can result in poor sleep quality, excessive daytime fatigue and, for some people, memory problems.

April 12, 2007 — An accident in which a Pinnacle Airlines Bombardier CRJ200LR ran off the end of the landing runway at Cherry Capital Airport in Traverse City, Michigan, U.S. The airplane was substantially damaged, but none of the 49 passengers and three crewmembers was injured in the crash, described in detail on p. 20.

Feb. 18, 2007 — An accident in which a Delta Connection Embraer ERJ-170, operated by Shuttle America, ran off the end of a runway at Cleveland Hopkins International Airport while landing in a snowstorm. None of the 75 people in the airplane suffered serious injury, but the airplane was substantially damaged. The NTSB said that the probable cause of the accident was the flight crew's failure to conduct a missed approach "when visual cues for the runway were not distinct and identifiable." Contributing factors included the captain's fatigue (*ASW*, 9/08, p. 22).

"The captain had been suffering from intermittent insomnia during the months preceding the accident," the NTSB said, noting that the captain told investigators that, at the time of the accident, he had been awake for 31 of the preceding 32 hours. The captain said that, although he told other crewmembers about his fatigue, he did not remove himself from duty or tell his company because he believed that he would have been fired.

"As a result, he placed himself, his crew and his passengers in a dangerous situation that could have been avoided," the NTSB said. "Shuttle America had an official attendance policy that allowed pilots to remove themselves from duty because of fatigue, but … in practice, the administration of this policy did not permit flight crewmembers to call in as fatigued without fear of reprisals."

Oct. 19, 2004 — An accident in which a Corporate Airlines BAE Systems Jetstream 32 crashed short of the landing runway in Kirksville, Missouri, U.S. The crash occurred as the pilots — at the end of a 14.5-hour duty day — were conducting a nonprecision approach in nighttime instrument meteorological conditions. Thirteen of the 15 people in the airplane were killed, and two received serious injuries. The NTSB said that the probable cause of the accident was "the pilots' failure to follow established procedures and properly conduct the approach and to adhere to established division of duties." Their fatigue "likely contributed to their degraded performance," the NTSB said.

— LW

Note

1. NTSB. Safety Recommendation Letter in reference to Recommendations A-08-44 and A-08-45. June 12, 2008.

In a multi-layered system, an incident can occur only when all the defensive systems fail."

'Best Practices' Attendance

The Pinnacle Airlines accident and other fatigue-related accidents and incidents illustrate the risks of fatigue, as well as the need for the industry to address fatigue-related factors in company policies and crewmember responsibilities, the NTSB said. Although industry and regulators often have relied on flight- and duty-time limits — such as the FAA's current regulatory requirement that a two-member flight crew be limited to eight scheduled flight hours between mandatory rest periods[7] — the NTSB and others say that these limitations alone are not sufficient to mitigate the risks of fatigue.

Among other things, the NTSB has recommended that the industry develop a "best practices attendance policy" to allow flight crewmembers to decline assignments if they believe that they are impaired by insufficient sleep.

In the final report on the Pinnacle Airlines accident, the NTSB said that long duty days can result in pilot fatigue and degraded performance.[8]

"Aviation accident data show that human performance–related airline accidents are more likely to happen when pilots work long days," the report said, citing a 1994 NTSB study that found that captains who had been awake longer than 12 hours made "significantly more errors" than those who had been awake for a shorter time period.

"Such errors included failing to recognize and discontinue a flawed approach; pilots often exhibited a tendency to continue the approach, despite increasing evidence that it should be discontinued," the report said. "Research and accident history also show that fatigue can cause pilots to make risky, impulsive decisions; become fixated on one aspect of a situation; and react slowly to warnings or signs. … Additionally, research shows that people who are fatigued become less able to consider options and are more likely to become fixated on a course of action or a desired outcome."

When accident investigators questioned how widespread fatigue was among Pinnacle pilots, the FAA principal operations inspector who oversaw Pinnacle operations estimated that 60 to 70 percent of company pilots who submitted event reports through the aviation safety action program (ASAP) cited fatigue as a factor in the event.

The report said that scientific studies indicate that people "typically underestimate their level of fatigue, especially when they are busy." For example, the report quoted the Pinnacle pilots as saying that they had not realized how tired they were until the airplane was established in cruise — a phase of flight in which workload typically is low. The report theorized that, if they had recognized the extent of their fatigue earlier, the accident pilots might have invoked a Pinnacle policy that allowed flightcrewmembers to remove themselves from trips because of fatigue.

'Company Resistance'

In its final report on another runway excursion accident in which fatigue was cited as a factor, the NTSB reviewed 5,200 reports by air carrier pilots involving fatigue-related events. The reports, filed with the U.S. National Aeronautics and Space Administration Aviation Safety Reporting System (ASRS) from 1996 to 2006, included discussions of 30 incidents in which pilots called in sick or fatigued.[9]

The outcomes of those calls varied. "Some of the air carrier pilots reported using such programs successfully, whereas other pilots reported that they hesitated to use such programs because of fear of retribution," the NTSB report said. "In addition, other pilots reported that they attempted to call in as fatigued but encountered company resistance."

The report cited as an example a February 2006 ASRS report in which a regional jet captain said that, after three consecutive early-report times, she and her first officer were "sort of robotic and tired." The first officer added, "I even called scheduling and spoke to a supervisor (twice), asking him to take me off the rest of the trip because I was so exhausted. He tried to work that out but said we were short-staffed. … I told him that I wouldn't call in fatigued because they didn't have the staffing."

Notes

1. Sturgell, Robert A. "No Rumble Strips." Opening remarks to *FAA Aviation Fatigue Management: Partnerships for Solutions Symposium*, Tysons Corner, Virginia, U.S. June 17–19, 2008.
2. ULR Crew Alertness Steering Committee and FSF Editorial Staff. "Lessons From the Dawn of Ultra-Long-Range Flight." *Flight Safety Digest*. Volume 24 (August–September 2005).
3. Fatigue management systems are referred to by several other names, including fatigue risk management systems, fatigue management schemes, fatigue countermeasures programs and alertness management programs.
4. NTSB. Safety Recommendation Letter in reference to Recommendations A-08-44 and A-08-45. June 12, 2008.
5. Stewart, Simon; Holmes, Alex. "The easyJet Fatigue Risk Management System (FRMS)." Paper presented at *FAA Aviation Fatigue Management: Partnerships for Solutions Symposium*, Tysons Corner, Virginia, U.S. June 17–19, 2008.
6. TC. *Developing and Implementing a Fatigue Risk Management System. TP 14575E*. April 2007.
7. Limited exceptions are permitted in case of "circumstances beyond the (operator's) control," such as inclement weather.
8. NTSB. *Runway Overrun During Landing, Pinnacle Airlines Flight 4712, Bombardier/Canadair Regional Jet CL600-2B19, N8905F, Traverse City, Michigan, April 12, 2007*. NTSB/AAR-08/02.
9. NTSB. *Runway Overrun During Landing, Shuttle America, Inc., Doing Business as Delta Connection Flight 6448, Embraer ERJ-170, N862RW, Cleveland, Ohio, February 18, 2007*. NTSB/AAR-08/01.

Further Reading From FSF Publications

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Caldwell, J. Lynn. "Managing Sleep for Night Shifts Requires Personal Strategies." *Human Factors & Aviation Medicine* Volume 46 (March–April 1999).

Flight Safety Foundation Fatigue Countermeasures Task Force. "Principles and Guidelines for Duty and Rest Scheduling in Corporate and Business Aviation." *Flight Safety Digest* Volume 16 (February 1997).

Easy Does It

BY MARK LACAGNINA

TCAS resolution advisories require rapid — but not radical — response.

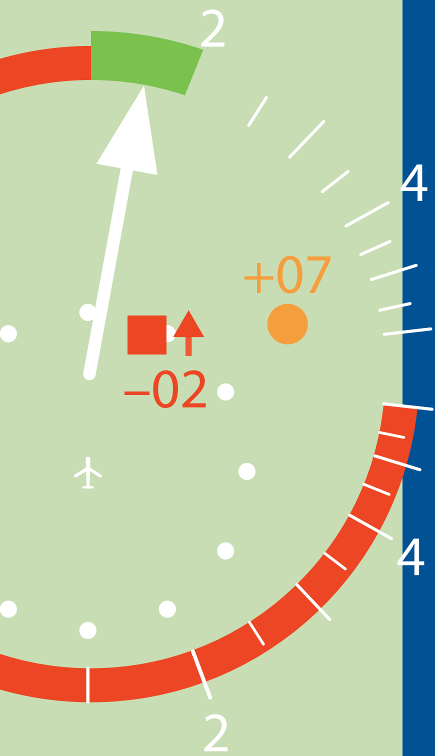
Recent reports of two accidents that resulted in serious injuries when the pilots performed excessive maneuvers during traffic-alert and collision avoidance system (TCAS) resolution advisories (RAs) suggest that while pilot educational efforts should continue to focus on the need to respond promptly and correctly to RAs, they also should emphasize that a gentle and smooth response is sufficient.

There is no need to panic when an RA is generated because enough time is available to carry out the recommended maneuver with normal control inputs. "Limit the alterations of the flight path to the minimum extent necessary to comply with the RA," says the International Civil Aviation Organization (ICAO),[1] which requires "airborne collision avoidance system equipment" — that is, the RA-generating TCAS II equipment — aboard large turbine airplanes in international commercial operations. ICAO also recommends that *all* aircraft be equipped with TCAS.

A brief description of how TCAS works might help in understanding how the system is intended to be used. Basically, TCAS obtains information about other aircraft up to 30 nm (56 km) away by transmitting interrogation signals that trigger replies from their altitude-encoding or selective-address transponders. The transponder replies yield information about the range, bearing and altitude of the other aircraft. From this information, TCAS computes the *closest point of approach* (CPA) for each aircraft, whether that point is within a programmed *protected volume* around the host aircraft and when the other aircraft, the *intruder*, will reach that point.

A traffic advisory (TA) is generated if the other aircraft will reach a CPA in the outer protected volume within a specific amount of time that varies from about 20 seconds below 1,000 ft to 48 seconds above Flight Level (FL) 200 (approximately 20,000 ft). A TA consists of an aural advisory — "traffic, traffic" — and a visual advisory, in which the symbol representing the intruder on the traffic display turns from white to amber.

A TA prompts the flight crew to use their traffic display as an aid in establishing visual contact with the intruder and to prepare themselves for a possible RA.



A flight attendant suffered a broken leg when this Embraer 170 pulled 2 g during an excessive RA maneuver.

Five-Second Margin

An RA is generated if the intruder continues to close and the CPA is projected to be within the inner protected volume of the host aircraft. Alert lead times range from about 15 seconds at 1,000 ft to 35 seconds above FL 200. (No RAs are issued below 1,000 ft.) The intruder's symbol turns red on the traffic display, and an aural advisory to "climb," "descend" or "adjust vertical speed, adjust" is issued. Red and green arcs appear on the RA display, typically built into the vertical speed indicator (VSI), to show the climb or descent rates that should be achieved or avoided.

The RA alert time includes a margin of five seconds for crew response. "For TCAS to provide safe vertical separation, initial vertical speed response is expected within five seconds of when the RA is displayed," says U.S. Federal Aviation Administration Advisory Circular (AC) 120-55B, *Air Carrier Operational Approval and Use of TCAS II.*

"Satisfy RAs by disconnecting the autopilot, if necessary, using prompt, positive control inputs in the direction and with the magnitude TCAS advises," the AC says. "To achieve the required vertical rate (normally, 1,500 fpm climb or descent), first adjust the aircraft's pitch using the suggested guidelines [Table 1]. Then, refer to the VSI and make all necessary pitch adjustments to place the VSI in the green arc.

"Excursions from assigned altitude, when responding to an RA, typically should be no more than 300 to 500 ft to satisfy the conflict."

'Excessive Maneuver'

Table 1 shows that the recommended initial pitch adjustment is 5 to 7 degrees when airspeed is below 200 kt. On Oct. 3, 2005, a cabin crewmember was seriously injured when an Embraer 170 was pitched 14 degrees nose-up in response to an RA.

The U.S. National Transportation Safety Board (NTSB) report on the accident is based on a limited investigation and provides relatively few details.[2] The airplane was being operated by Shuttle America as United Express Flight 7627 from Montreal to Washington Dulles International Airport with 41 passengers, two cabin crewmembers and two flight crewmembers. The first officer was the pilot flying.

The 170 was southbound at 3,000 ft in visual meteorological conditions (VMC) and about to turn right base for Runway 01R at Dulles when the airport traffic controller advised the flight crew of northbound traffic ahead at 2,500 ft. The controller told the Embraer crew to fly a southwesterly heading. "About the same time, the airplane's [TCAS] alerted the crew to the traffic and issued [an RA] to climb the airplane," the report said.

Recorded flight data indicate that the first officer increased the pitch attitude to 14 degrees nose-up, resulting in a peak vertical acceleration of +2.0 g — that is 2.0 times standard gravitational acceleration. NTSB said that the "excessive maneuver" was the probable cause of serious injuries, including a broken leg, sustained by a cabin crewmember. The 170 was not damaged.

The report said that if the first officer had followed pitch guidance on his primary flight display while responding to the RA, a vertical acceleration of only +0.75–1.25 g would have resulted.

Roller Coaster

Injuries were more numerous on Nov. 16, 2006, when a Boeing 757-200 was maneuvered excessively during an RA over the East China Sea.

Recommended Initial Reaction to 'Climb' or 'Descend' RA

Airspeed	Pitch Adjustment
0.80 Mach	2 degrees
250 KIAS below 10,000 ft	4 degrees
Approach below 200 KIAS	5 to 7 degrees

RA = traffic-alert and collision avoidance system resolution advisory; KIAS = kt indicated airspeed

Source: U.S. Federal Aviation Administration

Table 1

The 757, operated by Far Eastern Air Transport as Flight EF306, was en route from Taipei, Taiwan, to Jeju Island, South Korea, according to the report by the Aviation Safety Council (ASC) of Taiwan.[3]

The 757 departed from Taipei at 0041 coordinated universal time (UTC; 0841 local time) with 129 passengers, six cabin crewmembers and two flight crewmembers. The captain was the pilot flying.

The 757 was northbound in VMC at FL 390 and about 100 nm (185 km) from the destination at 0202 UTC when the flight crew was told by a controller at the Incheon (South Korea) Area Control Center to descend to FL 310. The 757 crew turned on the cabin seat belt sign before beginning the descent.

A Boeing 777 operated by Thai Airways was southbound at FL 340 on the same airway. TAs were generated aboard both aircraft when they were 12 nm (22 km) apart and 48 seconds from the projected CPA.

The 757 was descending through 34,052 ft at about 1,900 fpm when the TA was generated. Two seconds later, the controller said, "Far Eastern 308, stop, uh, immediately clear descend."

The controller explained to investigators that he had "lost awareness of the converging traffic for a minute" while he concentrated on identifying another aircraft on his radar display. When he returned his attention to the 757 and 777, he saw that they were about 13 nm (24 km) apart and that the 757 was at a higher altitude, and "instinctively" told the 757 crew to stop their descent.

While issuing that instruction, he saw that the 757's displayed altitude was 33,800, "so I thought that the urgent situation was over, and I instructed [the 757 crew] to descend more quickly." He also told the 777 crew to immediately turn right to a heading of 270 degrees.

The report said that the controller had failed to use standard phraseology that required use of the term "correction" between the instruction to "stop" and the instruction to "descend." The controller also used the wrong call sign — 308, rather than 306.

Confusion Reigns

The 757 captain did not thoroughly understand the controller's radio transmission but believed that he had been told to "stop descent." He engaged the autopilot altitude-hold mode, and the 757 leveled at 33,800 ft. The report said that if the captain had continued the descent, there would have been no conflict.

The captain's attention then was drawn to the TA depicted on his traffic display. "I noticed that the color of the traffic symbol turned from white to amber then red very quickly," he told investigators. The TA changed to an RA to descend.

At the same time, a coordinated RA to climb was generated aboard the 777. The distance between the aircraft was 9 nm (17 km), and the projected time to CPA was 35 seconds. The 777 crew responded promptly and correctly to their RA.

The 757 first officer erroneously told the controller that they were responding to a "TCAS climb" RA. The controller did not understand the transmission and replied, "Roger, now descend. Descend." The first officer said, "Negative. We follow TCAS."

The report indicated that the 757 captain's initial response to the RA was in accordance with the TCAS manufacturer's recommendation that "a prompt, smooth pitch change of 2 degrees to 6 degrees should be sufficient to resolve nearly all conflicts." The report said that a pitch change of 2 degrees would have resulted in a descent rate of about 1,600 fpm, which would have been adequate to resolve the conflict.

The captain told investigators, "When the RA aural tone 'descend, descend' was issued, I followed the TCAS red T-bar on the ADI [attitude director indicator] and pushed down the aircraft smoothly.

"Then, I looked outside [and saw] a flying object approaching rapidly in front of us. So, I pushed down the aircraft hard to avoid the traffic."

'Bounced … and Dropped'

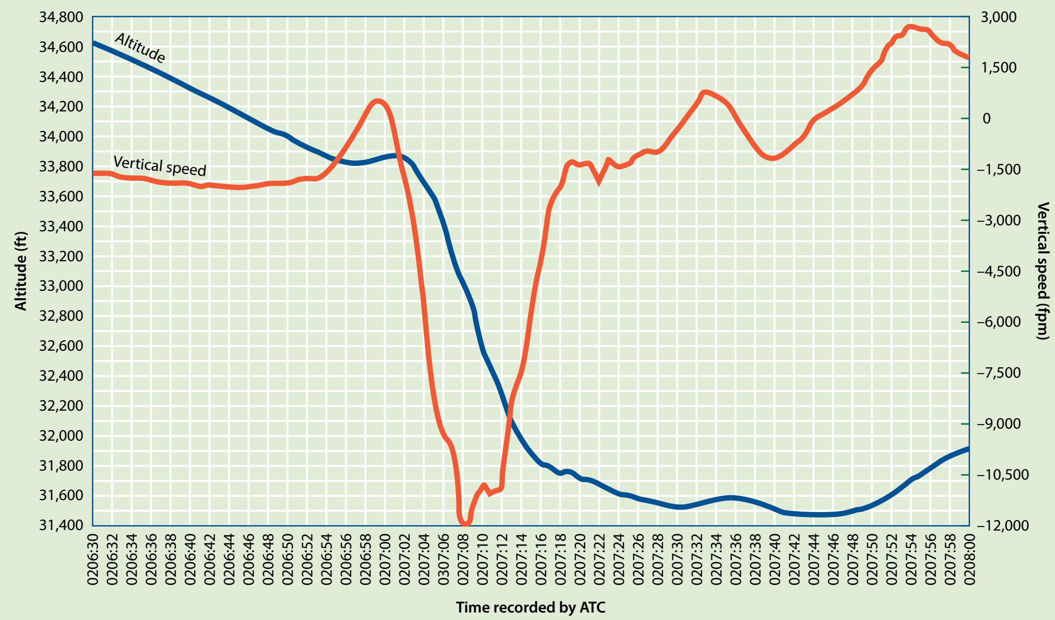
Recorded flight data indicated that the 757's pitch angle changed from +4 degrees to −18 degrees in four seconds. "The maximum vertical acceleration [was] −1.06 g," the report said. Descent rate peaked at 12,000 fpm (Figure 1).

The report indicated that the captain's recovery also was excessive, resulting in a peak vertical acceleration of +2.58 g for two seconds as the 757 was leveled at FL 310.

"When the occurrence happened, some passengers were bounced up to the cabin ceiling and dropped onto seat backs, handrails or cabin equipment," the report said. Unsecured cabin equipment, including a duty-free cart that was being moved to the galley by cabin crewmembers, became projectiles.

Four passengers sustained serious injuries. One seated near the rear of the cabin "bounced up several times and suffered an intracranial hemorrhage," the report said, noting that she also was struck by the duty-free cart. A nearby passenger suffered broken ribs and hemothorax, an accumulation of blood in the chest cavity. A

Boeing 757 Response to RA



RA = resolution advisory generated by traffic-alert and collison avoidance system; ATC = air traffic control

Source: Aviation Safety Council of Tawain

Figure 1

passenger returning from the lavatory to his seat "was bounced up and also encountered impact by the duty-free cart"; his injuries included a compound fracture of the left humerus, or upper arm bone. A passenger seated near the front of the cabin "encountered an impact with the ceiling and seat arm"; her injuries included fractured ribs, a fractured clavicle and hemothorax.

"The other 10 injured passengers and six cabin crewmembers sustained minor injuries such as contusions, sprains and abrasions," the report said, noting that none of the injured passengers had their seat belts fastened.

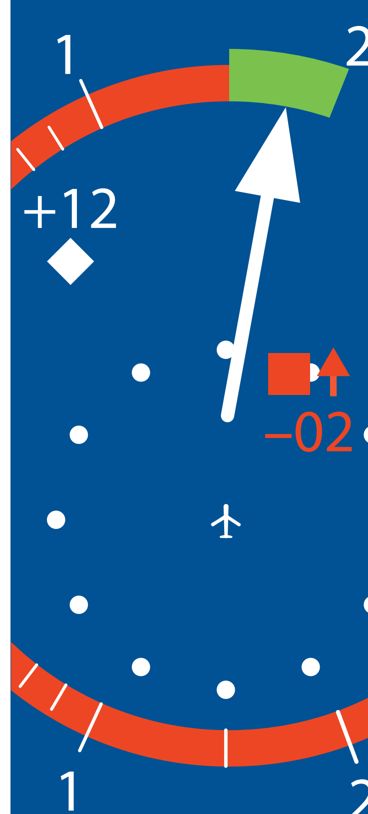
After the accident, the crew declared an emergency and landed on Jeju Island without further incident at 0228. Damage to the 757 consisted of three broken armrests and a punctured ceiling panel. No structural damage was found.

Based on the findings of the accident investigation, the ASC recommended that "all operators review their training programs to ensure that they contain the necessary training for flight crews to recognize and respond effectively to TCAS advisories."

The report said that the training should include theory and simulator practice. "The flight crew should have an understanding of how TCAS works. This includes an understanding of the alert thresholds, expected response to TAs and RAs, proper use of TCAS-displayed information, phraseology and system limitations."

Notes

1. ICAO. *Procedures for Air Navigation Services, Aircraft Operations.*
2. NTSB. Accident report no. NYC06LA002. June 30, 2008.
3. ASC. Final Report: *Far Eastern Air Transport Flight EF306, Boeing 757-200/Thai Airways International Public Company Ltd. Flight TG659, Boeing 777-300; A TCAS Event in Narrow Collision Avoidance at an Altitude of 34,000 Ft. and 99 NM South of Jeju Island, Korea, on November 16, 2006.* Aug. 15, 2008.



Dave Carbaugh, Boeing chief pilot for flight operations safety (right), receives the *Aviation Week & Space Technology* Distinguished Service Award from Tom Henricks, President of *Aviation Week* (middle), and Bill Voss, FSF president and CEO.

LONDON *Honors*

Flight Safety Foundation presented the Honeywell *Bendix Trophy* for Aviation Safety and the *Aviation Week & Space Technology* Distinguished Service Award in London in mid-July, a few days before the opening of the Farnborough International Airshow. The awards were presented at a dinner co-hosted by the Foundation and Honeywell at the Churchill Cabinet War Rooms, attended by special guests of the hosts and members of the international aerospace news media. This presentation venue — immediately preceding a major air show — was an innovation that may become an annual tradition.

The Bendix Trophy was presented to NATS, the U.K. air navigation service provider, for its Mode S Radar Tools Project. The project developed two important new tools using Mode S technology to help air traffic controllers maintain separation of climbing and descending aircraft in high-traffic terminal control areas.

NATS added pilot-selected flight levels to radar screen data blocks so that controllers can immediately see if an aircraft has been mistakenly programmed to fly at the wrong level and intervene much more quickly than when they had to wait to see aircraft actual altitude.

Another tool is a new vertical stack display showing the selected flight level of aircraft waiting for descent and landing clearances.

Dave Carbaugh, the Boeing chief pilot for flight operations safety, received the Distinguished Service Award for his lifetime achievements in aviation safety. His accomplishments include work to promote flight safety awareness, training, standard operating procedures and tools for pilots and maintenance technicians. A member of the IATA accident classification committee and various flight operations committees, Carbaugh briefs these committees on accidents, incidents and the lessons learned. He identifies issues that manufacturers and regulators must take into account, and has written numerous articles and contributed seminar presentations on subjects including tail strikes, in-flight upset recovery, wake turbulence and controlled flight into terrain.

Bill Casey, a Mode-S project leader, accepted the award on behalf of NATS, presented by FSF President and CEO Bill Voss (left) and Honeywell VP T.K. Kallenbach (right).

Approach and Landing Still Warrant Safety Emphasis

Accidents and fatalities rose in global commercial jet operations in 2007.

BY RICK DARBY

Approach and landing continue to predominate as the riskiest phases of flight for commercial jets worldwide, according to Boeing's latest statistical summary.[1,2]

Five of the 10 fatal accidents and 10 of the 14 major accidents occurred in the approach — including initial approach — and landing phases of flight in 2007.[3] That compares with four of the seven fatal accidents and five of the eight major accidents in 2006.

One accident during cruise, one during takeoff, one during climb, one during taxi and one during load/unload were categorized as fatal, major or both for 2007.

Boeing's data include accidents involving commercial jet airplanes heavier than 60,000 lb (27,216 kg) maximum gross weight, and exclude types manufactured in the Russian Federation or the Soviet Union.

There were 286 accidents involving passenger airplanes in the 1998–2007 period, compared with 285 in the 1997–2006 period (Table 1). Fatal accidents involving passenger airplanes in those periods numbered 78 and 75, respectively. Fewer cargo aircraft, 70, were involved in accidents in the most recent period than in the earlier period, 79. Fatal accidents involving cargo carriers also declined from 14 in 1997–2006 to 12 in 1998–2007.

Accidents, Worldwide Commercial Jet Fleet, by Type of Operation

	All Accidents		Fatal Accidents		Onboard Fatalities (External Fatalities)*	
Type of operation	**1959–2007**	**1998–2007**	**1959–2007**	**1998–2007**	**1959–2007**	**1998–2007**
Passenger	1,236	286	458	78	27,032 (773)	5,105 (185)
Scheduled	1,139	269	415	74	22,999	5,048
Charter	97	17	43	4	4,033	57
Cargo	218	70	67	12	237 (327)	42 (76)
Maintenance test, ferry, positioning, training and demonstration	110	8	40	0	186 (66)	0 (0)
Totals	**1,564**	**364**	**565**	**90**	**27,455 (1,166)**	**5,147 (261)**
U.S. and Canadian operators	498	72	169	13	6,078 (445)	365 (82)
Rest of the world	1,066	292	396	77	21,377 (721)	4,782 (179)
Totals	**1,564**	**364**	**565**	**90**	**27,455 (1,166)**	**5,147 (261)**

*External fatalities include ground fatalities and fatalities on other aircraft involved, such as helicopters or small general aviation airplanes, that are excluded.

Source: Boeing Commercial Airplanes

Table 1

2007 Airplane Accidents, Worldwide Commercial Jet Fleet

Date	Airline	Model	Accident Location	Phase of Flight	Description	Damage	Fatalities	Major Accident
Jan. 1	Adam Air	737-400	Near Sulawesi Island, Indonesia	Cruise	Loss of control	Destroyed	102	●
Jan. 13	Gading Sari Aviation Svcs	737-200	Kuching, Malaysia	Landing	Landing short	Destroyed		●
Jan. 25	Regional Airlines	F-100	Pau, France	Takeoff	Bird strike and overrun	Substantial	(1)	●
Feb. 4	Tampa Cargo	DC-8	Miami, Florida, U.S.	Landing	Right main landing gear collapse	Substantial		
Feb. 18	Shuttle America	EMB 170	Cleveland, Ohio, U.S.	Landing	Runway overrun	Substantial		
Feb. 21	Adam Air	737-300	Surabaya, Indonesia	Landing	Hard touchdown	Destroyed		●
Mar. 7	Garuda Indonesia	737-400	Yogyakarta, Indonesia	Landing	Runway overrun	Destroyed	21	●
Mar. 12	Biman Bangladesh Airlines	A310	Dubai, United Arab Emirates	Takeoff	Landing gear collapse	Substantial		
Mar. 16	Kish Air	MD-82	Kish Island, Iran	Landing	Gear-up landing	Substantial		
Mar. 23	Ariana Afghan Airlines	A300B4	Istanbul, Turkey	Landing	Landing excursion	Substantial		●
Apr. 17	Pakistan Intl. Airlines	A310	Karachi, Pakistan	Landing	Hard touchdown	Substantial		
Apr. 30	Royal Air Maroc	737-500	Bamako, Mali	Takeoff	High-speed rejected takeoff	Substantial		
May 5	Kenya Airways	737-800	Near Douala, Cameroon	Climb	Crashed after takeoff	Destroyed	114	●
May 25	Indonesia AirAsia	737-300	Medan, Indonesia	Landing	Hard landing	Substantial		
Jun. 28	TAAG Angola Airlines	737-200	M'banza Congo, Angola	Landing	Landed short	Destroyed	5 (1)	●
July 1	Air China	767-200	Beijing, China	Load/ Unload	Landing gear collapse	Substantial		
July 10	Sky King	737-200	Tunica, Mississippi, U.S.	Parked	Mechanic fell onto ramp		(1)	
July 12	Delta Air Lines	777-200	Atlanta, Georgia, U.S.	Tow	Flight attendant fall			
July 17	Aerorepublica	EMB 190	Santa Marta, Colombia	Landing	Runway excursion	Destroyed		●
July 17	TAM Linhas Aereas	A320	São Paulo, Brazil	Landing	Landing overrun	Destroyed	187 (12)	●
Aug. 18	Swiss European Airlines	RJ100	London , U.K.	Landing	Tail	Substantial		
Aug. 20	China Airlines	737-800	Okinawa, Japan	Taxi	Fuel-leak fire	Destroyed		●
Aug. 29	Myanmar Airways	F-28	Dawei, Myanmar	Landing	Landing gear collapse	Substantial		
Sept. 14	Magnicharters	737-200	Guadalajara, Mexico	Landing	Gear-up landing	Substantial		
Sept. 14	Avstar	737-200	Ndola, Zambia	Landing	Flight attendant seat failure			
Sept. 16	One-Two-Go Airlines	MD-82	Phuket, Thailand	Landing	Hard landing, fire	Destroyed	90	●
Sept. 23	Kenya Airways	737-300	Nairobi, Kenya	Load/ Unload	Cargo loader crushed		(1)	
Oct. 11	AMC Airlines	MD-83	Istanbul, Turkey	Landing	Flaps-up approach, overrun	Substantial		
Oct. 26	Philippine Airlines	A320	Butuan City, Philippines	Landing	Landing overrun	Destroyed		●
Oct. 28	Air Europa	737-800	Katowice, Poland	Approach	Struck approach lights	Substantial		
Oct. 28	AeBal	717-200	Palma, Spain	Load/ Unload	Wing struck by an airport passenger bus	Substantial		
Nov. 1	Mandala Airlines	737-200	Malang, Indonesia	Landing	Landing gear collapse	Substantial		
Nov. 7	Nationwide Airlines	737-200	Cape Town, South Africa	Takeoff	Lost engine during takeoff	Substantial		
Nov. 9	Iberia Airlines	A340	Quito, Ecuador	Landing	Landing overrun	Destroyed		
Nov. 30	Atlasjet Airlines	MD-83	Near Isparta, Turkey	Initial approach	Crashed in mountainous terrain	Destroyed	57	●
Dec. 12	Arkefly	767-300	Chania, Greece	Taxi	Wing tip struck tower	Substantial		
Dec. 14	JetBlue	EMB 190	New York, New York, U.S.	Parked	Struck by a taxiing 747	Substantial		
Dec. 30	TAROM	737-300	Bucharest, Romania	Takeoff	Struck maintenance vehicle	Substantial		
38 total accidents							**576 on-board (16) external**	

Intl = International; Svcs = Services

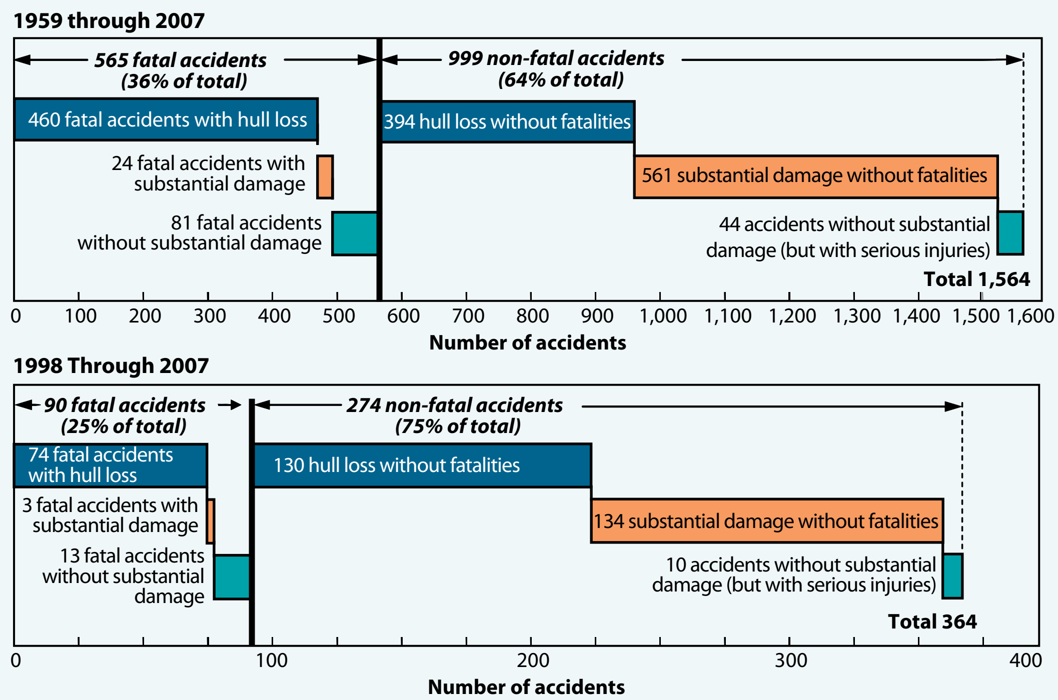
Note: Airplanes manufactured in the Commonwealth of Independent States or the Soviet Union and commercial airplanes used in military service are excluded.

Source: Boeing Commercial Airplanes

Table 2

Accidents by Injury and Damage

Worldwide Commercial Jet Fleet



Note: Airplanes manufactured in the Commonwealth of Independent States or the Soviet Union are excluded because of lack of operational data. Commercial airplanes used in military service are also excluded.

Source: Boeing Commercial Airplanes

Figure 1

Accidents totaled 38, with 576 on-board fatalities and 16 external fatalities (Table 2, p. 50). That compares with 28 accidents and 498 on-board fatalities in 2006.

In the most recent 10-year period, fatal accidents accounted for 25 percent of the total (Figure 1), compared with 36 percent of the total accidents for the 49-year period beginning in 1959. The number of fatal accidents without substantial airplane damage was 14 percent of the total of fatal accidents in both the past 10 years and from 1959 onward.

Among nonfatal accidents, those involving substantial damage accounted for 49 percent in 1998–2007, 56 percent in 1959–2007. Accidents without substantial damage but with serious injuries were 3.6 percent of the nonfatal accident total in the 10-year period, compared with 4.4 percent in the period from 1959 onward.[4]

The U.S. Commercial Aviation Safety Team (CAST)/International Civil Aviation Organization (ICAO) Common Taxonomy Team published updated categories and definitions for aviation occurrences that have been adopted by Boeing and other civil aviation organizations.[5] In the 1998–2007 period, "loss of control — in flight" was the CAST/ICAO category that accounted for both the highest number of on-board fatalities and the highest number of accidents (Figure 2, p. 52). By contrast, in the 1997–2006 period, there were more "controlled flight into or toward terrain" (CFIT) fatal accidents — 20 — than loss of control accidents — 19.

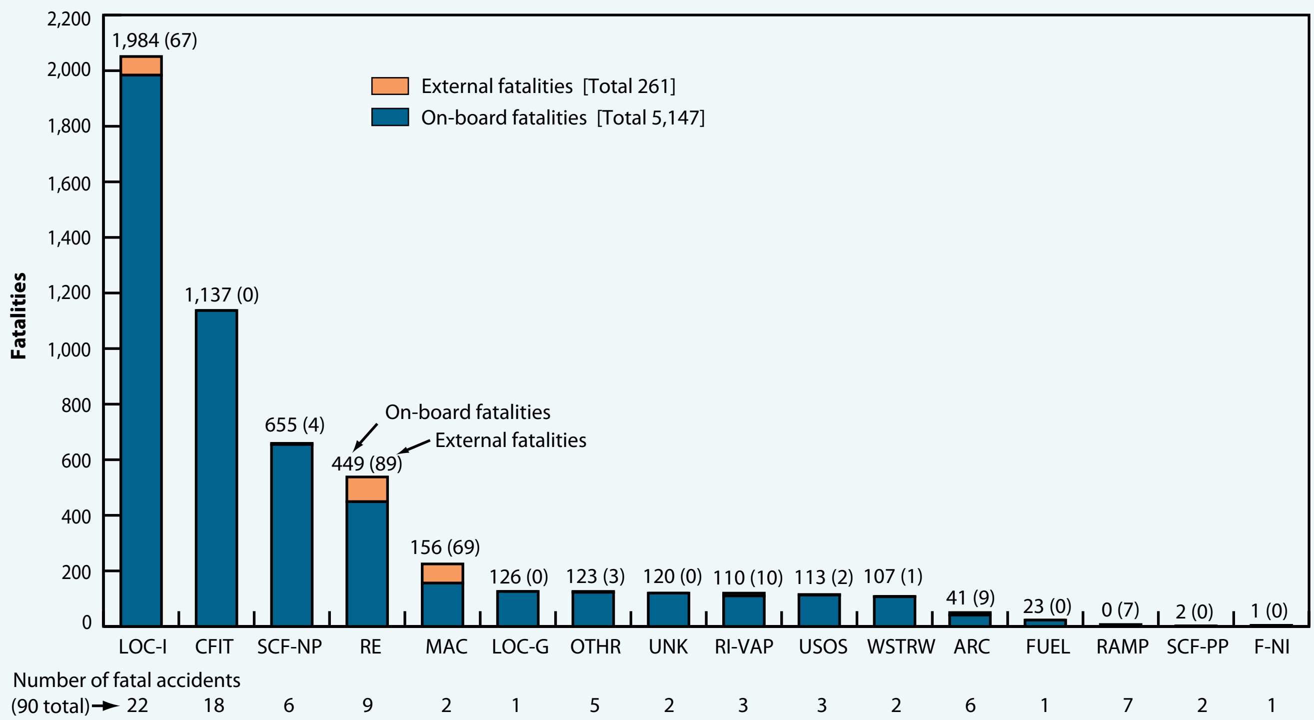
The 1,655 on-board fatalities from CFIT accidents in the preceding 10-year period was higher than the 1,137 in the most recent period, suggesting that the industry may be making progress in reducing CFIT.

Notes

1. Boeing Commercial Airplanes. *Statistical Summary of Commercial Jet Airplane Accidents: Worldwide Operations 1959–2007*. Available via the Internet at <www.boeing.com/news/techissues>.

2. Boeing adopts the ICAO definition of an *accident* as "an occurrence associated with the operation of an airplane that takes place between the time any person boards the airplane with the intention of flight and such time as all persons have disembarked, in which death or serious injury results from

Fatalities by CAST/ICAO Taxonomy Accident Category, Worldwide Commercial Jet Fleet, 1998–2007



CAST = Commercial Aviation Safety Team ICAO = International Civil Aviation Organization

ARC = abnormal runway contact; CFIT = controlled flight into or toward terrain; F-NI = fire/smoke (non-impact); FUEL = fuel related; LOC-G = loss of control (ground); LOC-I = loss of control (in flight); MAC = midair/near midair collision; OTHR = other; RAMP = ground handling; RE = runway excursion; RI-VAP = runway incursion (vehicle, aircraft or person); SCF-NP = system/component failure or malfunction (non-powerplant); SCF-PP = system/component failure or malfunction (powerplant); USOS = undershoot/overshoot; UNK = unknown or undetermined; WSTRW = wind shear or thunderstorm.

No accidents were noted in the following categories: AMAN = abrupt maneuver; ADRM = aerodrome; ATM = air traffic management/communications, navigation, surveillance; CABIN = cabin safety events; EVAC = evacuation; F-POST = fire/smoke (post-impact); GCOL = ground collision; ICE = icing; LALT = low altitude operations; RI-A = runway incursion (animal); SEC = security related; TURB = turbulence encounter.

Notes: Principal categories are as assigned by CAST. Airplanes manufactured in the Commonwealth of Independent States or the Soviet Union are excluded because of lack of operational data. Commercial airplanes used in military service are also excluded.

Source: Boeing Commercial Airplanes

Figure 2

being in the airplane, or direct contact with the airplane or anything attached thereto, or direct exposure to jet blast; the airplane sustains substantial damage; or the airplane is missing or is completely inaccessible." Occurrences involving test flights or the result of hostile action such as sabotage or hijacking are excluded.

3. Boeing defines *major accident* as one in which any of three conditions is met: the airplane was destroyed, or there were multiple fatalities, or there was one fatality, and the airplane was substantially damaged. Flight Safety Foundation supports the use of this term to identify the most severe accident category, in place of the traditional term *hull loss*, which the Foundation believes is more significant for insurance actuarial purposes than as a safety risk metric.

   Substantial damage is "damage or failure which adversely affects the structural strength, performance or flight characteristics of the airplane, and which would normally require major repair or replacement of the affected component."

4. A *serious injury* is one that "requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received; or results in a fracture of any bone (except simple fractures of fingers, toes or nose); or involves lacerations which cause severe hemorrhage, nerve, muscle or tendon damage; or involves injury to any internal organ; or involves second or third degree burns, or any burns affecting more than 5 percent of the body surface; or involves verified exposure to infectious substances or injurious radiation."

5. The taxonomy is described at <www.intlaviationstandards.org>.

Upgrading TCAS

A Eurocontrol-sponsored research project urges fast adoption of two improvements to reduce the risk of midair collisions.

REPORTS

Decision Criteria for Regulatory Measures on TCAS II Version 7.1

Eurocontrol Safety Issue Rectification Extension Plus Project (SIRE+ Project). Version 1.2. July 25, 2008. 47 pp. Figures, tables. Available via the Internet at <www.eurocontrol.int/msa/gallery/content/public/documents/SIRE+_WP7_69D_v1.2.pdf>.

The traffic-alert and collision avoidance system (TCAS) and air traffic control (ATC) radar coverage have made midair collisions of transport category aircraft rare. Nevertheless, the collision of a Tupolev Tu-154 and a Boeing 757 — both with TCAS installed — over Überlingen, Germany, in July 2002 showed that such events are still possible. To further reduce the risk, the European Organisation for Civil Aviation Equipment (EUROCAE) and RTCA have jointly developed revised minimum operational performance standards (MOPS) for traffic-alert and collision avoidance system II (TCAS II).

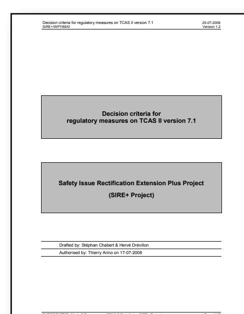
The new standards, known as TCAS II, version 7.1, are intended to improve pilot responses to resolution advisories (RAs) generated by the system. This paper by the SIRE+ Project, commissioned by Eurocontrol to study TCAS improvement, describes the rationale for the proposed TCAS II upgrade and urges a rapid transition to the new version.

There are two reasons in particular for changing the TCAS II MOPS, the paper says:

- The failure of TCAS to reverse some RAs when a reversal is required to resolve the collision; and,
- Frequent instances of flight crews' unintentional incorrect maneuvers in the wrong sense to "Adjust vertical speed" RAs. The "sense" of an RA is upward if it requires a climb or a limitation of the descent rate and downward if it requires a descent or a limitation of the climb rate.

"Due to the combination of these two safety issues, aircraft equipped with TCAS II version 7.0 face a midair collision risk … corresponding to one collision every three years in the European airspace," the paper says. "This exceeds the tolerable rate for catastrophic events related to equipment hazards by a factor of more than 25."

The first of the safety issues is designated SA01. "The design principles of TCAS II version 7.0 allow only one sense reversal, and care has been taken to ascertain the relative position of aircraft and their trajectories," the paper says. "Notably, reversing the ongoing RA is not permitted while aircraft are maneuvering in


Decision criteria for regulatory measures on TCAS II version 7.1 25-07-2008
SIRE+/WP7/69/D Version 1.2

Decision criteria for
regulatory measures on TCAS II version 7.1

Safety Issue Rectification Extension Plus Project
(SIRE+ Project)

Drafted by: Stéphan Chabert & Hervé Drévillon
Authorised by: Thierry Arino on 17-07-2008

EUROCONTROL Mode S Programme – DSNA & Egis Avia – SIRE+ Project Page 1/47 the vertical dimension and are at co-altitude. This can lead to delaying the decision to reverse if both aircraft are climbing or descending at similar vertical speeds. In the extreme, no sense reversal can be issued although it would be required. This problem can occur either in encounters with an unequipped aircraft or in TCAS-TCAS encounters."

Safety issue SA01 can occur when two aircraft are flying at the same flight level and are converging. A very late ATC instruction then induces the crew of one aircraft to maneuver, thwarting the initial RAs.

This scenario was involved in the Überlingen accident.

The recommended modification to TCAS II for reducing the frequency of such errors, called change CP112E, "brings two significant improvements to the reversal logic of TCAS II. First, it introduces a monitoring of the aircraft vertical rate in order to detect any non-compliance with the RA sense. Then, it includes a better projection of the current aircraft trajectories to identify encounters where two co-altitude aircraft maintain similar vertical rates. The former is designed to solve occurrences of SA01 between two TCAS-equipped aircraft, while the [latter] is intended to address occurrences of SA01 with an aircraft not equipped with TCAS. If CP112E detects either situation, it relaxes the conditions for reversing the ongoing RA, so that it can occur at an earlier time than with current TCAS II version 7.0."

Two specific scenarios, used as a reference for assessing all the possible start and completion times, represent possible extremes.

The second safety issue, designated SA-AVSA, occurs when flight crews unintentionally maneuver incorrectly in response to an RA of "Adjust vertical speed, adjust." The correct response is always a reduction in vertical speed — that is, a maneuver toward level flight.

"Several causes have been identified that can explain an unintentional opposite reaction to an AVSA RA, including a lack of training for this type of RA," the paper says. "However, the main factor remains the design of the AVSA RAs. First, the aural annunciation associated with AVSA RAs (i.e., 'Adjust vertical speed, adjust') does not give explicit instructions on the required maneuver. Then, some TCAS displays prove to be difficult to interpret when AVSA RAs are posted."

An example of this type of error occurred in French airspace in 2003. It involved an Airbus A320 level at Flight Level (FL) 270 (about 27,000 ft), heading south, and a second A320 cleared to climb to FL 260, heading north. The second aircraft's climb rate was about 3,300 fpm.

When passing through FL 253, its TCAS triggered an initial AVSA RA requiring a reduction in the climb rate to 1,000 fpm. However, the flight crew misinterpreted the RA and reacted by increasing the climb rate instead.

The closure rate increased between the two aircraft, and the initial AVSA RA was modified to a "Descend" RA. The flight crew followed this second RA, but the maneuver took some time to be effective and at the closest point separation was 300 ft vertically and 0.8 nm horizontally.

The proposed solution for the safety issue is designated CP115 and involves a change in the TCAS logic. Instead of a possibly confusing message of "Adjust vertical speed, adjust," and a display showing the adjustment in terms of a climb or descent rate, the RA would become a simple "Level off, level off."

The SIRE+ Project study examined various scenarios for starting and completing fleetwide implementation of version 7.1, and calculated the probabilities of collisions under each. Two specific scenarios, used as a reference for assessing all the possible start and completion times, represent possible extremes:

- The "do nothing" scenario — no implementation at all between the beginning of 2009 and the end of 2020.
- The "immediate full equipage scenario" — implementation is completed as early as the beginning of 2009.

"When doing nothing, the number of collisions increases to more than five in 2020," the paper says. "The curve is not linear, because the number of flight hours flown in the European airspace is not constant and increases with time. This implies an increase in the risk of collision each year, as the probability of collision due to issues SA01 and SA-AVSA remains constant. If current TCAS II version 7.0 units are not upgraded to version 7.1, the estimates used in the present study indicate that the probability of a first collision at end of 2011 is very high.

"With the assumption of an immediate full equipage, the curve is also not linear for the same reason. The estimates used in the present study indicate that the probability of a first collision at the end of 2018 is very high. The number of collisions is, in January 2020, more than four times lower than if existing TCAS units are not upgraded."

The study evaluated various intermediate assumptions, including a "forward fit" process, in which version 7.1 is introduced only as new aircraft enter the fleet, and two retrofit processes: "The first one assumes a progressive retrofit of aircraft, whereas the second one assumes that airlines will wait before equipping, and then rush to retrofit their aircraft very late, close to the end of the transition phase."

The paper concludes, "The investigation of several possible scenarios for the implementation of TCAS II version 7.1 in Europe indicates that the requirement for the entry into force of this safety revision of the TCAS II equipment must be associated to an aggressive scheme in order to maximize the benefits it provides. This should notably include retrofitting the current European fleet, preferably on a progressive basis. A regulation solely based on forward fit brings only very limited benefits."

Further, the paper says, "The Überlingen accident and recurring severe incidents resulting from safety issues SA01 and SA-AVSA could have been avoided with TCAS II version 7.1. It is therefore strongly recommended that [implementation] of this new version be achieved as rapidly as possible."

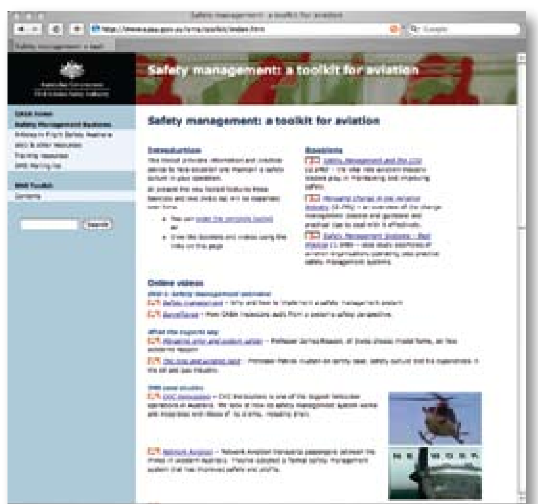
WEB SITES

Safety Management: A Toolkit for Aviation, <www.casa.gov.au/sms/toolkit/index.htm>

Australian Civil Aviation Safety Authority (CASA) is offering a "tool kit [that] provides information and practical advice to help establish and maintain a safety culture in your operation," its Web site says.

The tool kit currently features three booklets and two DVDs. Instructions to order DVDs and view videos online are provided. Online viewing is free. Booklets may also be downloaded or printed and can be read separately or as an accompaniment to the DVDs. Both DVDs are in color and contain sound and supplemental text.

DVD 1 contains eight videos about safety management:



- Two give an overview of safety management, *Why and How to Implement a Safety Management System (SMS)* and *How CASA Inspectors Audit From a Systems Safety Perspective*;

- Four videos are case studies describing how four organizations — CHC Helicopters, Network Aviation, Skytrans Airlines and Quantaslink-Sunstate Airlines — apply SMS and safety culture best practices; and,

- Two videos are presentations by safety management specialists. James Reason discusses "how accidents happen" in *Managing Error and System Safety,* and in *The Long and Winding Road,* Patrick Hudson focuses on "safety case, safety culture and his experiences in the oil and gas industry."

DVD 2 contains nine videos that discuss industry best practices in organizations engaged in various aviation operations. In each video, company representatives describe how SMS was implemented in their organization and how employees operate in the SMS environment. Organizations include a company that provides airborne maintenance, a corporate jet charter company, air charter and airline companies, flight training centers and a helicopter company with multiple operations ranging from emergency medical assistance to offshore work.

The Web site contains SMS articles from the magazine *Flight Safety Australia* and a list of risk management and safety systems resources from Australia, Canada, the United Kingdom and the United States. Many of the materials are full text and can be printed or read online at no charge.

Readers can also subscribe to an SMS mailing list to receive updated information.

The International Federation of Air Line Pilots' Associations, <www.ifalpa.org>

The International Federation of Air Line Pilots' Associations (IFALPA) Web site says, "Our work, our aims and our commitment [are] achieving the highest standards of air safety worldwide. You will … find [on the site] information about the many training and other services we offer to pilots and the industry as a whole."

IFALPA has made portions of this Web site open to non-members: safety bulletins, briefing leaflets, IFALPA position statements, IFALPA's legal directory and other materials.

Briefing leaflets address various topics of pilot interest. Currently, leaflet categories

are airport and ground environment, aircraft design and operation, air traffic services, human performance and medicine, dangerous goods, security, and legal issues. Each category contains multiple titles.

Recent titles include "Use of External Lights to Mitigate Runway Incursion Risk" in the airport and ground environment category and "Health Preservation" in the human performance and medical category. Leaflets are one to 12 pages, in color, and free to download or print. Most of the leaflets have been issued in 2008.

Most safety bulletins are location- or equipment-specific, but some have general application, such as "Revised Guidance for In-Flight Passenger Electronic Equipment Fires" and "Cabin Air Quality Issues." Safety bulletins are archived to 2001.

Free wind shear posters — "Their Causes," "Warning and Alerting" and "Pilot's Rules" — can be downloaded and printed from the Web site.

Interested readers are invited to sign up to receive notification when new leaflets and other publications are added to the site.

IFALPA's journal, *InterPilot*, and *IFALPA News: The Global Voice of Pilots* are archived. They are in color and cover editions from 2005 to 2008. Issues may be printed, saved or read online at no charge.

— Rick Darby and Patricia Setze

Empty Tank

Faulty fuel indication leads to in-flight engine shutdown.

BY MARK LACAGNINA

The following information provides an awareness of problems in the hope that they can be avoided in the future. The information is based on final reports by official investigative authorities on aircraft accidents and incidents.

JETS

Refueling Procedure Relied on Gauges

Boeing 747-300. No damage. No injuries.

The 747 was nearing the top of descent during a positioning flight from Jakarta, Indonesia, to Melbourne, Victoria, Australia, on Feb. 4, 2007, when the flight crew noticed that the no. 3 fuel tank boost pump low-pressure lights had illuminated and the fuel quantity indicator for the no. 3 tank was reading zero.

"After completing the appropriate 'non-normal' checklist items, the crew shut down the no. 3 engine," said the Australian Transport Safety Bureau (ATSB) report. "The crew assessed the proximity to alternative airports, and a decision was then taken to continue to Melbourne."

The aircraft was about 256 km (138 nm) northwest of Melbourne when the crew declared an urgency with air traffic control (ATC). They landed the 747 at Melbourne without further incident.

"The subsequent examination of the aircraft by maintenance personnel found no evidence of a fuel leak," the report said. "A magnastick check of the fuel remaining in the no. 3 main fuel tank showed it to be empty. The fuel remaining in the other main tanks was reported as being 7,162 kg [15,789 lb], which was greater than the minimum fuel required by the operator and by [regulation] to be aboard the aircraft at the end of the landing roll." (A magnastick is a direct-reading mechanical fuel-level indicator similar to a dipstick.)

Examination of the fuel quantity indicator for the no. 3 tank showed that it was malfunctioning. "The manner in which the malfunction occurred led the crew to believe there was a greater quantity of fuel remaining in that tank than was actually present," the report said. "The examination determined that the malfunction was due to either an electrical problem, water contamination or a combination of both."

The 747 had been on the ground in Jakarta for more than two days before the incident flight began. After landing there, the crew had conducted a fuel-discrepancy check, comparing fuel quantity indicating system readings with those of the "fuel used" gauges. The readings were within the prescribed limits.

The aircraft then was "pre-fueled" to a total quantity of 50,390 kg (111,090 lb). "The station engineer at Jakarta advised [investigators] that … the purpose of pre-fueling was to reduce the possibility of water contamination by displacing the air space in the fuel tanks and also to allow any free water that may be present in the fuel to settle prior to preparing the aircraft for the next flight," the report said. "Maintenance personnel could not recall if a water drain had been conducted at any time after this pre-fueling. During the subsequent 64 hours between the pre-fueling and the final uplift of fuel for the flight to Melbourne, heavy and continuous rain was reported at Jakarta."

While preparing for departure from Jakarta, the crew noticed that the total fuel quantity reading was 52,820 kg (116,447 lb) — or 2,430 kg (5,357 lb) more than the reading after the pre-fueling was completed. "After the completion of the final up-lift, the total fuel quantity displayed by the cockpit fuel quantity indicator gauges was 65,100 kg [143,519 lb]," the report said. Required fuel for the flight was 62,200 kg (137,126 lb).

The flight engineer and a ground engineer discussed whether a magnastick check was required before departure. "After referring to operational documentation, it was concluded that a magnastick check was not required," the report said.

Twice during the climb to cruise altitude, the flight engineer noticed that the no. 3 tank fuel quantity reading momentarily decreased by about 3,000 kg (6,614 lb), accompanied by illumination of the fuel configuration warning light. "The crew discussed the indication problem and undertook numerous checks in order to confirm the serviceability status of the fuel quantity indicating system," the report said. "They determined that the fluctuating indications were probably due to an intermittent or unreliable no. 3 main tank fuel quantity indicator."

Revised refueling procedures had reduced the likelihood of discovering the malfunction before flight.

Investigators found that revised refueling procedures adopted by the operator before the incident had reduced the likelihood of discovering the malfunction before flight. "In part, the revision to the operator's refueling procedures assumed a serviceable fuel quantity indicating system for establishing the reference baseline fuel quantity on board prior to the refueling," the report said. "The revised procedures were also based on the assumption that, should the fuel quantity indicating system develop a fault, the system would not indicate a larger quantity than actually present."

Previously, on-board fuel quantity prior to refueling was determined by cross-checking fuel quantity indications with the arrival-fuel reading recorded on the aircraft's technical log plus any fuel used after arrival — by the auxiliary power unit or during engine maintenance work, for example. Also, magnastick checks of fuel quantity previously were required when the aircraft was on the ground more than 36 hours; the revised procedures increased the interval to 72 hours.

"As a result of this occurrence, the operator is implementing a series of safety actions, including amending its refueling procedures and conducting a risk assessment of its fuel management policies and procedures," the report said.

Go-Around Decision Made Too Late

Cessna Citation 560. Destroyed. Four fatalities.

The approach controller cleared the flight crew to conduct the localizer approach to Runway 24 at Carlsbad, California, U.S., the morning of Jan. 24, 2006, but the crew reported the 4,897-ft (1,493-m) runway in sight and canceled their instrument flight rules flight plan.

The airport traffic control tower had been closed overnight and was not yet in operation. The automated weather observation system reported the surface winds from 040 degrees at 6 kt. The captain told the first officer that he would "land to the east," on Runway 06, said the U.S. National Transportation Safety Board (NTSB) report. However, the captain continued the straight-in visual approach to Runway 24.

The Citation was high, and a descent rate of 3,000–4,000 fpm initially was maintained to establish the aircraft on a proper final approach glide path. Several enhanced ground-proximity warning system (EGPWS) "sink rate" alerts and a "pull up" warning were generated.

"During the approach sequence, the captain maintained an airspeed that was approximately 30 kt higher than the correct airspeed for the aircraft's weight, resulting in the aircraft touching down about 1,500 ft [457 m] further down the runway than normal and much faster than normal," the report said.

The first officer asked the captain if they were going to go around. "Yeah," the captain replied. "Let's get out of here." The Citation lifted off the runway but struck a localizer antenna platform 304 ft (93 m) beyond the threshold and then crashed into a commercial storage building. All four occupants were killed; no one on the ground was hurt.

Engine Failure Traced to Broken Blade

Dassault Falcon 900B. Substantial damage. No injuries.

About 10 minutes after departing from Farnborough, England, for a commercial flight to Tel Aviv, Israel, on Jan. 20, 2007, the flight crew heard a loud bang and saw the no. 3 engine fire light illuminate. "The pilots carried out the engine fire procedures for the no. 3 engine and declared a mayday to the London Terminal Control Centre," said the U.K. Air Accidents Investigation Branch (AAIB) report.

"The crew were given immediate radar vectors for [London] Gatwick Airport, the nearest airport. The crew accepted Gatwick since it was fully equipped with rescue and fire fighting services, and had a runway of sufficient length." The Falcon was landed without further incident.

Examination of the no. 3 engine showed that the low-pressure turbine assembly had failed. "Debris from the turbine assembly ruptured the engine casing, penetrated the cowling and caused slight damage to the horizontal stabilizer," the report said. "Many of the fractured parts were lost overboard, but the available evidence indicated that the failure had probably resulted from the fracturing of a low-pressure turbine blade, leading to the loss of rotational restraint for the turbine stators and the spin-up and non-contained rupture of the stators."

Signs of a casting defect — intergranular cracking — were found on the fractured blade. The report said that a "substantial number" of turbine blade fractures in Honeywell TFE731 engines in 1999 and 2000 had prompted the manufacturer to "take measures," including recommending replacement of the suspect blades. "However, failures of blades that were not from the suspect batch subsequently occurred," the report said. The blade design and manufacturing process were being revised when the Falcon accident occurred.

As a result of the investigation, the AAIB recommended that the U.S. Federal Aviation Administration (FAA) review the manufacturer's plans to prevent TFE731 turbine assembly failures and require compliance with existing nonmandatory service bulletins.

Nosegear Collapses During Pushback

Boeing 737-300. Substantial damage. No injuries.

The pushback from the gate at Pittsburgh International Airport the morning of July 27, 2006, was described as "smooth and steady" until the tug driver began to slow the tug to a stop so that the tow bar could be disconnected. A ground crewmember heard a "snap" and an FAA inspector observing the pushback said that the airplane's nose moved up and down "like a horse throwing its head" before the nosegear collapsed.

The NTSB report said that the probable cause of the accident was the "tug driver's inadvertent movement of the tug's gearshift lever from forward to reverse." Examination of the 737's nosegear showed that the lower drag brace had buckled in compression and fractured due to overstress.

Examination of the tug showed that the gearshift lever was defective. "It would not lock in the neutral gate and could be moved easily through the gate between the forward and reverse gears," the report said. A new shift mechanism was installed on the tug before it was returned to service.

Examination of the tug showed that the gearshift lever was defective.

Hot Brakes Cause Fire on Takeoff

Raytheon Hawker 800XP. Substantial damage. No injuries.

The flight crew rejected the first of three takeoff attempts at John Wayne/Orange County Airport in Santa Ana, California, U.S., the afternoon of Oct. 29, 2007, when the pilot sensed that the engines were not spooling up normally as he advanced the throttles. "The airplane was taxied back for takeoff and three minutes later was cleared for takeoff again," the NTSB report said.

The crew rejected the second takeoff attempt when the automatic performance reserve system warning light illuminated immediately after the system was armed at 20–30 kt. "The airplane taxied back once again and was cleared for take-off nine minutes later," the report said.

At about 85 kt during the third takeoff attempt, the crew felt a vibration and heard a "pop" as the Hawker began to drift left. "The pilot called for an abort and was able to keep the airplane on the runway, eventually traveling into the overrun area at the end of the runway," the report said. "The tower notified the flight crew that there was smoke and fire coming from the left main gear. The pilot ordered an emergency evacuation, and all [eight] occupants exited the airplane without injury."

Examination of the main landing gear showed that the brakes had overheated, causing the fusible plugs in both wheels to melt. In addition, the tires on the left main gear had burst, and tire debris had struck and severed a hydraulic line. Fluid that leaked from the severed line ignited when it contacted the hot brakes.

The report noted that the Hawker flight manual requires a 25-minute waiting period to allow the brakes to cool after a takeoff rejected below 90 kt. "After two or more successive rejected takeoffs, a waiting period of 45 minutes is required," the report said.

TURBOPROPS

Deviation From SOPs Leads to Overrun

Hawker Siddeley 748. Minor damage. No injuries.

The flight crew had conducted a cargo flight from Coventry, England, to Jersey, Channel Islands, the morning of March 8, 2006, but were delayed by weather for the next leg, a 15-minute flight to Guernsey. While waiting, the commander briefed the copilot for the instrument landing system (ILS) approach to Runway 27 at Guernsey, which required a minimum runway visual range (RVR) of 550 m (1,800 ft). The briefing — and the subsequent approach — did not adhere to company standard operating procedures (SOPs), the AAIB report said.

Guernsey was reporting 1,500 m (5,000 ft) RVR, a 100-ft broken ceiling, winds from 230 degrees at 21 kt, moderate rain and fog when the crew departed from Jersey. While providing radar vectors for the ILS approach at Guernsey, ATC told the 748 crew that a de Havilland Dash 8 had just landed.

As briefed, the copilot called out "500 [ft] above" decision altitude and said that he was "looking out [for the runway]." The aircraft descended slightly below the glideslope, and the commander advised the copilot that he was correcting. About 20 seconds later, however, the EGPWS generated a "glideslope" alert. "There was no verbal challenge from the copilot," the report said.

The EGPWS then generated a "minimums" alert, and the commander asked the copilot if he could see anything. "The copilot replied that he could see the lights [and touchdown marks] just to the left," the report said. "He asked the commander if he was visual, and the commander confirmed that he was."

The commander told investigators he saw that the aircraft's left wing tip was over the right edge of the runway and maneuvered toward the centerline of the 1,463-m (4,800-ft) runway. The 748 touched down with 400 to 550 m (1,312 to 1,805 ft) of runway remaining. Investigators calculated that this was sufficient to bring the aircraft to a stop, using normal technique.

However, a partial flap setting had been selected because of the crosswind, and the copilot failed to disengage the fine pitch stops after touchdown, which would have enabled propeller-blade pitch to be reduced below 18 degrees to provide additional drag.

In addition, maximum wheel braking was not applied after touchdown. "The commander did not immediately appreciate how far down the runway he had landed and delayed maximum braking until he saw the end of the runway," the report said. Perceiving abnormal deceleration, possibly due to aquaplaning on the wet runway, the commander manually modulated brake pressure, which inadvertently reduced the effectiveness of the anti-skid braking system.

The 748 overran the runway and came to a stop in a grassy area 145 m (476 ft) beyond the end. Damage was limited to two main-gear tires that were cut when they struck light fixtures.

'VMC Roll' Induced During Missed Approach

Embraer Bandeirante. Destroyed. One fatality.

En route on a cargo flight from Bangor, Maine, U.S., the night of Jan. 13, 2005, the pilot was not able to land at the scheduled destination, Manchester, New Hampshire, because of adverse weather conditions. While holding, the pilot radioed company personnel, who told him to return to the company's base in Bennington, Vermont, the NTSB report said.

The Bandeirante's right engine lost power during the flight, and the pilot told ATC that he was diverting to Keene, New Hampshire, which had 1 mi (1,600 m) visibility and a 100-ft ceiling. Keene was 45 nm (83 km) closer than Bennington, which had 10 mi (16 km) visibility and a 2,900-ft ceiling.

The pilot asked ATC for radar vectors "to keep it in tight" on the ILS approach to Runway 02 at Keene. The airport traffic control tower was not in operation, and no radio transmissions were received from the pilot after he reported that the airplane was established inbound on the localizer and acknowledged the approach controller's termination of radar services and instruction to change to the airport advisory frequency.

Several witnesses reported thick fog near the airport. One witness saw the Bandeirante flying low, in and out of clouds, with its wings rocking substantially as it neared the airport. The report said that the airplane's flaps were fully extended when the pilot brought the left engine to full power in an apparent attempt to go around. The flight manual specifies a 25-percent flap setting for a single-engine approach. "The high power setting, slow airspeed and full flaps combination resulted in a minimum control speed (VMC) roll," the report said. "The airplane came to rest inverted on Runway 02, about 90 ft [27 m] from the approach end."

Broken Trim Tab Causes Severe Vibration

Beech King Air C90A. Substantial damage. No injuries.

The pilot said that the King Air suddenly began "shuddering with a severe high-frequency vibration" while flying at 12,000 ft, en route with six passengers from Tulsa, Oklahoma, U.S., to Manhattan, Kansas, the night of Sept. 22, 2007. He told NTSB investigators that the vibration "was in the entire airframe, not specifically the flight controls, so I had no clue where it was coming from."

The vibration continued when the pilot reduced power from the left engine but stopped when he reduced power from the right engine. The pilot said, however, that a few minutes after he shut down and secured the right engine, the vibration "returned just as bad as before."

The pilot diverted to Emporia, Kansas, and landed the King Air without further incident. He noted that the vibration had stopped when the landing gear was extended during the approach.

The vibration stopped when the pilot reduced power from the right engine.

"During a post-flight inspection, the pilot observed that the right elevator trim tab push rod was broken," the report said. According to maintenance records, the bolts and bushings on the trim tab attachment mechanism had been replaced 101.5 flight hours before the incident occurred. The report said that the trim tab had not been reinstalled properly; excessive torque had been applied to a bolt and nut on a clevis (a U-shaped fitting on the push rod), resulting in a fatigue crack that propagated through the threaded portion of the push rod.

Ice Chokes Engine on Skydiving Flight

Nomad N22B. Substantial damage. No injuries.

The pilot was attempting to climb to 10,000 ft, where 13 parachutists would jump from the aircraft near Cambridgeshire, England, on Aug. 12, 2007. "During the climb, the pilot saw a large cumulonimbus cloud ahead, the top of which was above the aircraft," the AAIB report said. "He believed the aircraft would be able to climb over it; but, at about 8,500 ft, the aircraft unexpectedly entered cloud."

The pilot initiated a descent and turned back toward Chatteris Airfield. "[He] selected the engine anti-ice on, but not in sufficient time to prevent the left engine [from] running down due to icing," the report said. "His attempts to restart the left engine were unsuccessful, and he therefore prepared for a single-engine landing."

The Nomad broke out of the clouds at 4,000 ft. The pilot said that he conducted the approach at 80 kt, the best single-engine rate of climb speed, rather than the normal 70 kt. "This, combined with the damp grass runway surface and reduced reverse thrust available, caused the aircraft to overrun the end of the runway," the report said. "The nosewheel subsequently entered a ditch, causing the nose leg to collapse. Neither the pilot nor the parachutists, who had remained on board throughout, were injured."

PISTON AIRPLANES

Twin Beech Stalls During Missed Approach

Beech H-18. Destroyed. One fatality.

The pilot was conducting a cargo flight from Wichita, Kansas, U.S., to Great Bend, Kansas, the morning of Feb. 9, 2007. The destination airport was reporting 2 mi (3,200 m) visibility and a 500-ft ceiling. Several pilots had reported icing conditions below 6,000 ft in the area, the NTSB report said.

ATC cleared the pilot to conduct the ILS approach to Runway 35 and approved a change to the airport's common traffic advisory frequency when the airplane reached the outer marker. Witnesses saw the airplane about 200 ft above the ground west of the runway and on a northwesterly heading before it entered a climbing left turn. "The published missed approach procedure instructed the pilot to initiate a climbing left turn to a fix and hold," the report said.

One witness then saw the airplane emerge from the clouds in a 20-degree nose-down attitude and on a southeasterly heading. Investigators determined that the pilot had lost control of the twin Beech during the missed approach. The airplane stalled and descended to the ground with the flaps and landing gear extended.

"Local authorities reported observing a 'layer of ice' on the leading edges of both wings when they arrived at the accident site," the report said. "Examination of the airframe and engines revealed no anomalies that would have precluded normal operations."

Battery Short Triggers Electrical Failure

Rockwell Aero Commander 500S. No damage. No injuries.

The electrical system failed when the Commander encountered severe turbulence for about 15 seconds while cruising in instrument meteorological conditions at 9,000 ft about 130 km (70 nm) southeast of Mackay, Queensland, Australia, during a positioning flight from Mackay to Thangool the night of Sept. 4, 2007.

"The pilot unintentionally lost control of the aircraft when he leaned forward on the control column yoke and used both hands to search in the dark for a torch [(flashlight) that had fallen] on the cockpit floor," the ATSB report said.

After recovering the flashlight and illuminating the instrument panel, the pilot, who was alone in the aircraft, saw that the Commander was in a 40-degree bank and descending through 8,000 ft at 2,000 fpm. "The pilot managed to regain control of the aircraft with one hand while holding the torch in the other," the report said. "He climbed the aircraft back to 9,000 ft and brought the aircraft onto the original heading to Thangool."

The pilot checked the circuit breakers and avionics equipment master switch. He also turned off the battery switch to reduce the risk of an electrical fire. "This action restored electrical power to the aircraft," the report said. "The pilot then checked the engine-driven alternators for correct charge rates and amperage, and these appeared to be operating correctly."

Examination of the electrical system revealed an internal short in one of the two 12-volt lead-acid batteries. The electrical system operated normally after the battery was replaced.

"It is most likely that the internal short … drew all the current from the aircraft's alternators, causing a complete loss of lighting and power to instruments and radios," the report said. "When the battery master switch was turned off, the power drain from the alternators to the defective battery was isolated and essential electrical power was restored."

Unsecured Cowling Separates in Flight

Piper Chieftain. Destroyed. No injuries.

The Chieftain was cruising at 4,000 ft during a positioning flight from Melbourne, Florida, U.S., to Orlando, Florida, the afternoon of July 11, 2007, when the pilot heard a loud bang, felt a strong vibration and saw that the right side of the windshield and the right side window had broken, and the upper cowling on the right engine was missing.

The pilot shut down the right engine and feathered the propeller. "Although full power was applied to the left engine, the airplane would not maintain altitude," the NTSB report said. The pilot landed the airplane, undamaged, on a field of scrub brush; but, about five minutes later, the grass under the left engine ignited, and the resulting brush fire consumed the airplane.

Investigators found that the right engine cowling had not been secured properly during maintenance performed on the Chieftain the day before the accident. "The mechanic who had been working on the outboard side of the engine stated that he was not certain that he fastened the three primary outboard cowl fasteners before he left the airplane during the installation to retrieve a stepladder," the report said. The three fasteners were found unlatched. "When asked about the security of the cowling during his preflight inspection, the pilot said that he 'just missed it,'" the report said.

HELICOPTERS

Tail Rotor Separates During Air Tour

McDonnell Douglas 369FF. Destroyed. One fatality, three serious injuries, one minor injury.

While conducting an air tour flight 1,500 ft above ground level near the shoreline of Haena, Kauai, Hawaii, U.S., on March 11, 2007, the pilot heard two loud bangs before the helicopter pitched nose-down and yawed right. "The right yaw developed into a tight spin, and he realized that he had 'lost his tail rotor,'" the NTSB report said.

The pilot said that he adjusted collective control and throttle to "slow down the yaw a little" and attempted to land in an open field, but the helicopter struck trees on the edge of the clearing. The pilot sustained minor injuries; one passenger was killed; and three passengers were seriously injured.

Examination of the helicopter revealed that the tail rotor blades had separated. NTSB determined that the probable cause of the accident was "the fatigue failure of the tail rotor blade root fitting due to a manufacturing defect."

Fuel Leak Causes In-Flight Fire

Enstrom F-28. Destroyed. No injuries.

The pilot was conducting a private flight over a wooded area near Newtownmountkennedy, Ireland, on Aug. 2, 2007, when he noticed that the engine had begun to run roughly and the oil temperature was high but still "in the green." The cockpit then rapidly filled with white smoke. "There were loud noises from the engine compartment, and a total loss of power occurred," the Irish Air Accident Investigation Unit report said.

The pilot's vision was substantially affected by the smoke, but he was able to turn away from higher terrain and conduct an autorotative descent toward a large, up-sloping, green field. "However, unknown to the pilot, and most likely unseen by him as well, there were two sets of wires criss-crossing this green field," the report said.

The F-28 struck a wire, touched down heavily, bounced and came to rest on its left side. The pilot and passenger escaped injury and exited the helicopter before it was engulfed by flames.

Investigators determined that fuel had leaked from a hole that had been worn through the metal braiding on the hose between the engine's fuel control unit and fuel distributor. The wear had occurred during an extended period of contact with either the magneto or an oil pipe. The report said that a clamp intended to prevent contact between the fuel hose and these components was either absent, mispositioned or distorted.

Preliminary Reports

Date	Location	Aircraft Type	Aircraft Damage	Injuries
Aug. 3, 2008	Port Hardy, British Columbia, Canada	Grumman G-21 Goose	destroyed	5 fatal, 1 serious, 1 none
The amphibious airplane crashed in a forest about 10 minutes after departing from Port Hardy to fly to a logging camp on Chamiss Bay.				
Aug. 3, 2008	Pitt Meadows, British Columbia, Canada	Beech King Air A90	substantial	4 serious, 4 minor
The King Air was departing for a skydiving flight when one engine lost power. The other engine lost power during an attempted return to the airport, resulting in a forced landing on a farm field.				
Aug. 4, 2008	Aniak, Alaska, U.S.	Piper Navajo	substantial	1 serious, 2 minor, 4 none
The pilot landed the Navajo on a gravel bar in a river after the left engine lost power on initial climb for a commuter flight to Grayling.				
Aug. 5, 2008	Weaverville, California, U.S.	Sikorsky S-61N	destroyed	9 fatal, 4 serious
The helicopter crashed after losing power while departing at an elevation of 5,935 ft to transport personnel battling a wildfire.				
Aug. 9, 2008	Ndundu, Indonesia	Pilatus PC-6 Turbo Porter	substantial	1 fatal
The airplane crashed in mountainous terrain while transporting food from Wamena to Ndundu.				
Aug. 13, 2008	Mogadishu, Somalia	Fokker F.27	destroyed	3 fatal
The cargo airplane struck a telecommunications antenna and crashed during an approach in adverse weather to K-50 Airport, 50 km (27 nm) southwest of Mogadishu.				
Aug. 16, 2008	Tukums, Latvia	Piper Navajo	destroyed	1 fatal, 8 serious
The Navajo crashed during an emergency landing in adverse weather during a flight from Riga to Tukums.				
Aug. 17, 2008	Warwickshire, England	Cessna 402C, Rand KR-2	destroyed	5 fatal
The four occupants of the 402 and the pilot of the KR-2 were killed when the airplanes collided on final approach to Coventry Airport.				
Aug. 18, 2008	Beaverlodge, Alberta, Canada	Cessna 337	destroyed	1 fatal, 1 serious
The airplane crashed about 15 nm (28 km) west of Beaverlodge during a fire-patrol flight.				
Aug. 18, 2008	Santo Domingo, Dominican Republic	Cessna Citation I/SP	destroyed	1 fatal
The Citation crashed in the ocean soon after departing from Santo Domingo for a flight to San Juan, Puerto Rico.				
Aug. 20, 2008	Madrid, Spain	McDonnell Douglas MD-82	destroyed	154 fatal, 18 serious
The MD-82 crashed and burned during takeoff for a flight to the Canary Islands. The flaps reportedly were not set properly for takeoff.				
Aug. 22, 2008	Moab, Utah, U.S.	Beech King Air A100	destroyed	10 fatal
A technical problem occurred soon after takeoff, and the King Air crashed in the desert during an emergency landing.				
Aug. 24, 2008	Zacapa, Guatemala	Cessna 208 Caravan	destroyed	10 fatal, 4 serious
The Caravan crashed after the flight crew reported engine problems during a charter flight from Guatemala City to El Estro.				
Aug. 24, 2008	Bishkek, Kyrgyzstan	Boeing 737-200	destroyed	68 fatal, 22 NA
A thunderstorm was over the airport when the 737 crashed soon after takeoff for a flight to Tehran, Iran.				
Aug. 27, 2008	Jambi, Indonesia	Boeing 737-200	substantial	2 serious, 123 none
The 737 overran the 2,000-m (6,562-ft) runway on landing and injured two people who were working in a rice field.				
Aug. 28, 2008	Las Vegas, Nevada, U.S.	Piper Chieftain	destroyed	1 fatal
Soon after departing for a positioning flight to Palo Alto, California, the pilot reported an engine problem and said that he was returning to North Las Vegas Airport. The Chieftain struck power lines on final approach and crashed into a house. No one on the ground was hurt.				
Aug. 30, 2008	Toacaso, Ecuador	Boeing 737-200	destroyed	3 fatal
The airplane was on a nighttime ferry flight from Caracas, Venezuela, to Latacunga, Ecuador, when it struck the Iliniza Volcano at about 17,000 ft.				
Aug. 31, 2008	Cobá, Yucatán, Mexico	Cessna 208 Caravan	destroyed	2 NA
After radio contact with air traffic control was lost during a flight from Cancún to Campeche, one of the pilots used a mobile telephone to report mechanical problems. The pilots reportedly survived the subsequent crash and were rescued the next day.				

NA = not available

This information, gathered from various government and media sources, is subject to change as the investigations of the accidents and incidents are completed.

A D V E R T I S E M E N T

Cockpit Smoke Solution

According to Air Safety Week, at least once a day somewhere in North America a plane has to make an unscheduled or emergency landing because of a smoke and in-flight fire event.

Statistics from FAA Service Difficulty Reports clearly show that in-flight fires, smoke or fumes are one of the most significant causes of unscheduled or emergency landings and account for 3 precautionary landings per day based on 1,089 events during a 10 month period in 1999.

A pilot encountering smoke in the cockpit so thick that the instruments cannot be seen can utilize a relatively simple device, which provides a clear view.

The Emergency Vision Assurance System (EVAS) provides a clear space of air through which a pilot can see flight instruments and out the front windshield for landing. The pilot still relies on the oxygen mask for breathing, smoke goggles for eye protection and employs approved procedures for clearing smoke from the aircraft. When smoke evacuation procedures are not sufficient, EVAS provides emergency backup allowing the pilot to see and fly the aircraft to a safe landing.

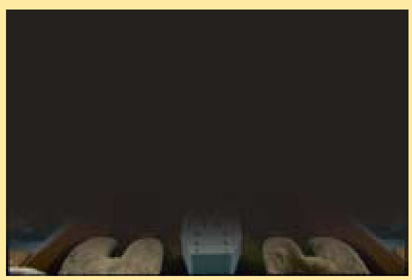
EVAS measures 3 x 8.5 x 10 inches when stowed, the approximate space of a Jeppessen navigation manual. When needed, the pilot removes the IVU (Inflatable Vision Unit) from the EVAS case and pulls a tab to activate the system. The IVU inflates with one lobe above and one below the glareshield. According to EVASWorldwide, the manufacturer, the whole process takes 15-20 seconds. The pilot leans forward, placing his smoke goggles in contact with the EVAS clear window, giving him an unimpaired view of both vital instruments and the outside world.

After it is activated, EVAS is continually pressurized with filtered cockpit air to maintain volume, and preserve a clear view. The device is independent of aircraft power, relying on a self-contained battery-power supply, pump and filters in each storage case. EVAS systems are designed to run for at least two hours, and filter down to .01 microns. The system requires virtually no installation.

While FAA regulations require smoke detectors, fire extinguishers, smoke goggles and oxygen masks, pilots point out that these safeguards and all other systems and equipment for flight safety are useless if the pilots cannot see to control and land the aircraft.

EVASWorldwide uses a fleet of mobile cockpit demonstration units to show potential customers the benefits of the system. EVAS demonstrations use a fog generator to reduce cockpit vision so the pilot cannot see his hand in front of his face. Smoke goggles offer no vision improvement, though they do protect the eyes. After EVAS is deployed, the pilot can clearly see both the vital instruments and out through the windshield. It is truly an amazing experience. Most pilots are sold on the benefits of EVAS on the spot.

Normal cockpit visibility



Uncontrolled smoke in the cockpit –No visibility

Uncontrolled smoke in the cockpit –Visibility with EVAS

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