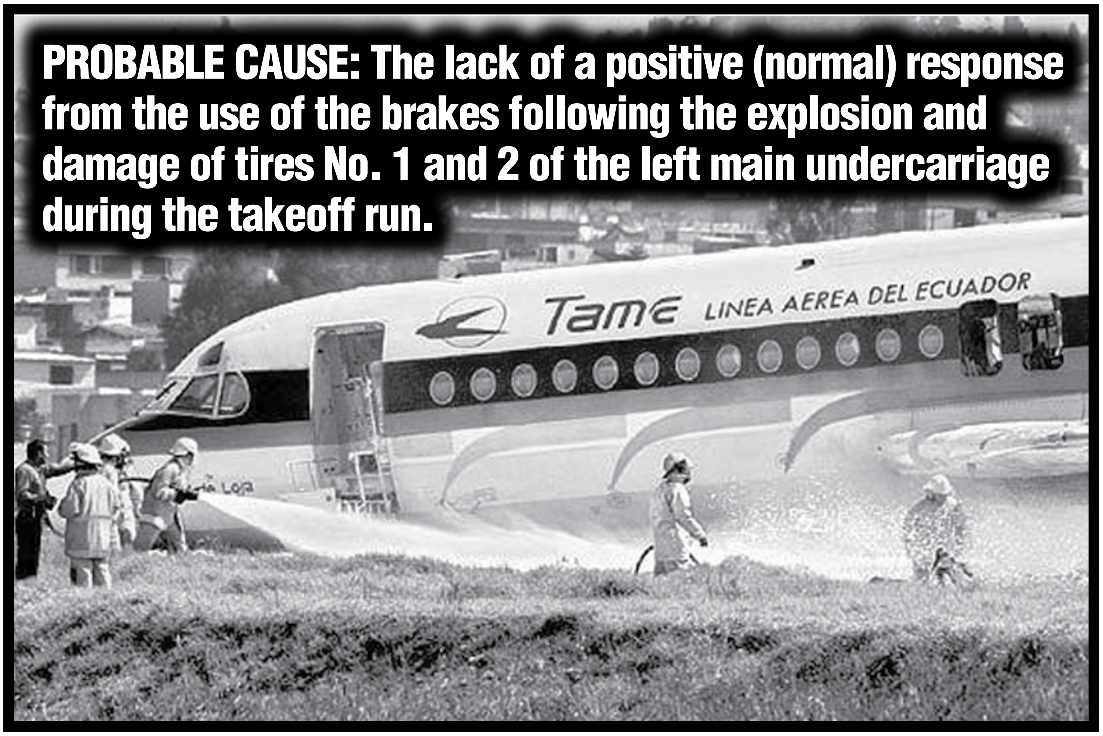
ISASI FORUM

"Air Safety Through Investigation"

APRIL–JUNE 2010



Contents

Features

Departments

About the Cover

This TAME Ecuador Fokker F-28 Fellowship 4000, Flight 120, was on a regular scheduled flight from Quito to Cali on Jan. 17, 2003. For initial departure at Mariscal Sucre Airport (UIO) (Ecuador), the takeoff was on Runway 35, a 3,120-meters-long asphalt runway. At 2,110 meters down the runway, while the airplane was accelerating through 125 knots IAS, both tires of the left-hand main undercarriage blew. Abandoning the takeoff, the pilots managed to keep the airplane on the runway. As the airplane overran the end of the runway, the nose gear collapsed. The aircraft came to rest 81 meters past the end of the runway. A small fire erupted in the area of the left-hand main gear. This was quickly contained by the fire service. There were no fatalities among the 77 occupants. The aircraft was damaged beyond repair. Probable cause: The lack of a positive (normal) response from the use of the brakes following the explosion and damage of tires No. 1 and 2 of the left main undercarriage during the takeoff run. Photo: ISASI Proceedings 2009

ISASI FORUM "Air Safety Through Investigation"

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AIR SAFETY INVESTIGATORS
INCORPORATED AUGUST 31, 1964

ISASI Adopts 'Criminalization' Position

By Frank Del Gandio, ISASI President

I am very pleased to report that our Society has become a signatory to the Joint Resolution Regarding Criminalization of Aviation Accidents, originally jointly published in the fall of 2006. The criminalization resolution was originally developed through the efforts of the Flight Safety Foundation, the Civil Air Navigation Services Organisation (CANSO), the Royal Aeronautical Society (RAeS), and the Academie Nationale de l'Air et de l'Espace (ANAE) in France. Signatories have expanded over the years to include the European Regions Airline Association, the Professional Aviation Maintenance Association, and the International Federation of Air Traffic Controllers Associations.

Your International Council first began discussing the subject of criminalization of accident investigations at its Sept. 7, 2008, meeting in Halifax. Discussion pointed out that there is significant variance among the world's legal systems, leading to a variety of State approaches to this issue. Any position ISASI might take must accommodate these differences, and ISASI could not attempt to limit the statutory authority of a sovereign State.

Accordingly, the joint criminalization resolution was circulated among the Council members for study. Dave King, European Society president, and Peter Williams, New Zealand councillor, consolidated Council member comments and began drafting an ISASI position for discussion at the May 2009 Council meeting. That gathering produced another lengthy discussion of the subject. The Council reviewed cases of persons prosecuted or being charged and agreed on the threat such practices by some States pose to occurrence investigations. Council members were asked to thoroughly review the joint resolution document for possible adoption by ISASI. The vote to adopt was unanimous.

The joint resolution reads, in part, as shown below.

"***Recognizing*** the importance in civil aviation accident investigations in securing the free flow of information to determine the cause of accidents and incidents and to prevent future accidents and incidents;

Recognizing the actions taken recently by the International Civil Aviation Organization in promoting amendments to Annex 13–Aircraft Accident and Incident Investigations to the Convention on International Civil Aviation, encouraging Contracting States to adopt by November 2006 certain actions to protect the sources of safety information;

Recognizing the importance of preventing the inappropriate use of safety information, including the increasing use of such information in criminal proceedings against operational personnel, managerial officers, and safety regulatory officials;

Recognizing that information given voluntarily by persons interviewed during the course of safety investigations is valuable and that such information, if used by criminal investigators or prosecutors for the purpose of assessing guilt and punishment, could discourage persons from providing accident information, thereby adversely affecting flight safety;

Recognizing that under certain circumstances including acts of sabotage and willful or particularly egregious reckless conduct, criminal investigations and prosecutions may be appropriate;

Concerned with the growing trend to criminalize acts and omissions of parties involved in aviation accidents and incidents;

Recognizing that the sole purpose of protecting safety information from inappropriate use is to ensure its continued availability to take proper and timely preventative actions and to improve aviation safety;

Considering that numerous incentives, including disciplinary, civil, and administrative penalties, already exist to prevent and deter accidents without the threat of criminal sanctions;

Being mindful that a predominant risk of criminalization of aviation accidents is the refusal of witnesses to cooperate with investigations, as individuals invoke rights to protect themselves from criminal prosecution, and choose not to freely admit mistakes in the spirit of ICAO Annex 13 for the purpose of preventing recurrence;

Considering that the vast majority of aviation accidents result from inadvertent, and often multiple, human errors;

Being convinced that criminal investigations and prosecutions in the wake of aviation accidents can interfere with the efficient and effective investigation of accidents and prevent

The Joint Resolution Regarding Criminalization of Aviation Accidents was originally developed through the efforts of the Flight Safety Foundation, the Civil Air Navigation Services Organisation (CANSO), the Royal Aeronautical Society (RAeS), and the Academie Nationale de l'Air et de l'Espace (ANAE) in France. Signatories have expanded over the years to include the European Regions Airline Association, the Professional Aviation Maintenance Association, and the International Federation of Air Traffic Controllers Associations.

Criminal investigations can and do hinder the critical information gathering portions of an accident investigation, and subsequently interfere with successful prevention of future aviation industry accidents.

the timely and accurate determination of probable cause and issuance of recommendations to prevent recurrence;

BE IT THEREFORE RESOLVED that the below organizations:

1. Declare that the paramount consideration in an aviation accident investigation should be to determine the probable cause of and contributing factors in the accident, not to punish criminally flight crews, maintenance employees, airline or manufacturer management executives, regulatory officials, or air traffic controllers. By identifying the "what" and the "why" of an accident, aviation safety professionals will be better equipped to address accident prevention for the future. Criminal investigations can and do hinder the critical information gathering portions of an accident investigation, and subsequently interfere with successful prevention of future aviation industry accidents.
2. Declare that, absent acts of sabotage and willful or particularly egregious reckless misconduct (including misuse of alcohol or substance abuse), criminalization of aviation accidents is not an effective deterrent or in the public interest. Professionals in the aviation industry face abundant incentives for the safe operation of flight. The aviation industry every day puts its safety reputation and human lives on the line, and has a remarkable safety record that is due in large measure to the current willingness of operators and manufacturers to cooperate fully and frankly with the investigating authorities. The benefit of gaining accurate information to increase safety standards and reduce recurring accidents greatly outweighs the retributive satisfaction of a criminal prosecution, conviction, and punishment. Increasing safety in the aviation industry is a greater benefit to society than seeking criminal punishment for those "guilty" of human error or tragic mistakes.
3. Urge States to exercise far greater restraint and adopt stricter guidelines before officials initiate criminal investigations or bring criminal prosecutions in the wake of aviation disasters. Without any indicia of proper justification for a criminal investigation or charges, the aviation system and air disaster victims and their loved ones are better served by resort to strong regulatory oversight and rigorous enforcement by national and international aviation authorities, and by pursuit of claims through civil justice systems to obtain compensation.
4. Urge States to safeguard the safety investigation report and probable cause/contributing factor conclusions from premature disclosure and use directly in civil or criminal proceedings. Although use of official accident reports may save criminal investigators the considerable expense of conducting an entire separate investigation, a considerable and serious risk exists of diverting these reports from their original purpose, as technical causes often cannot be equated to legal causes necessary when establishing either civil or criminal liability. In addition, use of relatively untrained and inexperienced technical "experts" by prosecutorial or judicial authorities, as compared to official accident investigating authorities, can result in flawed technical analyses and a miscarriage of justice, while interfering with the official accident investigation.
5. Urge national aviation and accident investigating authorities to: (i) assert strong control over accident investigations, free from undue interference from law enforcement authorities; (ii) invite international cooperation in the accident investigation under Annex 13; (iii) conduct professional investigations to identify probable cause and contributing factors and develop recommendations in a deliberative manner, avoiding any "rush to judgment"; (iv) ensure the free and voluntary flow of essential safety information; (v) provide victims' loved ones and their families with full, accurate, and precise information at the earliest possible time; and (vi) address swiftly any acts or omissions in violation of aviation standards."

Endorsement of this joint criminalization resolution demonstrates our belief that the current trend of criminalizing aviation accidents has a deleterious effect on the appropriate investigation of said occurrences, the finding of contributing factors and probable causation, and the formulation of recommendations to prevent recurrence.

Endorsement of this joint criminalization resolution demonstrates our belief that the current trend of criminalizing aviation accidents has a deleterious effect on the appropriate investigation of said occurrences, the finding of contributing factors and probable causation, and the formulation of recommendations to prevent recurrence.

The resolution may be viewed in its entirety on the Society's website: www.isasi.org. ◆

THE ACCIDENT 'CAUSE' STATEMENT

Is It Beyond Its Time?

(This article is adapted with permission from the author's paper entitled The Accident "CAUSE" Statement—Is It Beyond Its Time? *presented at the ISASI 2009 seminar held in Orlando, Fla., Sept. 14-18, 2009, which carried the theme "Accident Prevention Beyond Investigations." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org. The opinion, facts, and conclusions expressed in this article are those of the author; the content is not a product of the U.S. National Transportation Safety Board.—Editor)*

After many years of use, and abuse, is it time to omit this traditional step in the Annex 13 investigation process?

By Robert MacIntosh (MO0996), Chief Advisor, International Safety Affairs, National Transportation Safety Board, Washington, D.C., USA

The recent ICAO Accident Investigation and Prevention Meeting, AIG 2008, conducted in Montreal in October 2008, presented an opportunity for 190 Member States and observer organizations to review any needed changes in the protocols of Annex 13, Aircraft Accident and Incident Investigation. The agenda included a topic of frequent and long-standing discussion among air safety investigators, the issue surrounding determination of "causes" or "probable cause" related to Annex 13 air safety investigations.

The subject was discussed in considerable detail in two sessions of the AIG 2008 meeting. Some attendees commented that it was essential to emphasize "risk mitigation and accident prevention" in concert with Safety Management System (SMS) principles rather than to focus directly on causation. In addition, many opinions were expressed by several State delegations and international organizations regarding both the use and misuse of a causal statement.

Of particular concern within the air safety community is the entry of final accident reports into the judicial process in various States. However, outside our investigator community, we must recognize that there continue to be major expectations regarding the results of the Annex 13 investigative efforts by various groups and the public. For example, the news media, legislators, consumer groups, and families of victims all expect their government to conduct an investigation and provide answers to the "how and why" of any major accident. Therein lies a question, "How best can the final report meet the expectations of the public and other groups while meeting the very focused and sole objective of Annex 13, 'an investigation for the prevention of accidents, not to apportion blame or liability'?"

In aviation circles, it has been a long tradition that we continue to learn from the past. Therefore, let's indulge for a moment in the history surrounding the Convention on International Civil Aviation (Chicago 1944) and the guidance developed for accident investigation. Following the initial meetings of those pioneers, by 1946 a newly formed Accident Investigation Division proposed some applicable standards and recommended practices (SARPs) to the Air Navigation Commission. In the administrative practice still used today, the proposals went to the Member States for comment and then back to the Air Navigation Commission and the Council for consideration. The final product titled Aircraft Accident Inquiry was adopted as Annex 13 to the Convention and became effective Sept. 1, 1951.

The new Annex 13, first edition, consisted of only four pages of text. There were three definitions: aircraft, aircraft accident, and state of registry. There was a note indicating the report on the inquiry would normally include, in addition to the findings, a summary of evidence, and other essential information on which the findings were based. There was no mention of "cause" in that first edition of Annex 13, and that version prevailed for the next 15 years.

So how was the idea of cause introduced? It was the second edition of Annex 13, effective in August 1966, that defined the inquiry as "the process leading to determination of the cause of an aircraft accident including the completion of the relevant report." This second edition further expanded the inquiry definition to include in the SARPs a Paragraph 5.4 as follows: "The inquiry instituted by a State shall include the investigation and the obtaining and recording of all available relevant information; the analysis of the evidence; the determination, if possible, of the cause; completion of the report; and the making of recommendations when appropriate." Further, this second edition of Annex 13 provided the format of a report calling for separate paragraphs: one containing (a) the most significant determinations of the

Robert MacIntosh has a long career in the aviation industry, including NTSB investigator-in-charge, airline director of safety, airplane manufacturer staff engineer/accident investigator, and 22 years as a U.S. Air Force officer pilot and safety director. He has more than 8,000 hours of flying experience and holds resident bachelor of arts and master of business degrees.

THE ACCIDENT 'CAUSE' STATEMENT

Is It Beyond Its Time?

fact finding and analysis and (b) the cause or probable cause(s), and a final paragraph containing recommendations. From this history, one can see that the issues of cause and safety recommendations have been interrelated within ICAO Annex 13 protocols for more than 40 years.

Before we move on from the historical perspective we should note one more interesting development. The fourth edition of Annex 13, which became effective April 1976, changed the title to Aircraft Accident Investigation, replacing the word "Inquiry" with "Investigation," and adding more inclusive definitions of investigation, safety recommendation, and cause. At that time, the plurality of cause was recognized and reflected in a further definition as, "action(s) omission(s), event(s), conditions(s), or a combination thereof, which led to the accident or incident."

So with this brief view of the background of the developing issues surrounding "cause," what are the benefits and drawbacks surrounding the pronouncement of cause? Does a causal statement serve the intended purpose of Annex 13—to promote the prevention of accidents and incidents; or is a causal statement simply an adjunct item working to the detriment of the stated purpose, instead providing support for blame and liability? Depending upon your perspective of the process of accident and serious incident investigation, there are many answers to that question.

And it is useful at this point to update ourselves and examine the evolution of thinking that has taken place since the 1970s. The current edition of the ICAO Safety Management Manual (SMM) provides an interesting overview comprised of three periods of air safety investigation—the traditional era, the human era, and the organizational era. Despite the description of a "traditional era" safety investigation as an activity for "funereal purposes," the SMM does recognize the historic contribution that the safety professionals, engineers, regulators, and flight training experts have made to the safety improvements enjoyed in commercial air transportation. The hull loss rates have gone from the historic 10 per million departures at the full entry into the jet age to below 5 per million in the mid 1970s to less than 0.1 per million departures in today's air transport fleet. These efforts are laudable, and remarkable as commercial jet transport airplanes have opened up the air transportation scene around the world.

Like most modern advances, these civil aviation achievements have come with some consequences and the Annex 13 accident investigation process has its critics. The formal process of investigation has been described by some as simply a search for flaws and shortcomings in technology or errors committed by operational personnel, i.e., pilot error. As a consequence, the causal statement in the traditional era of investigation came to indicate blame in different degrees and under different guises. Critics allege that very little emphasis has been placed on the "why" and "how" of an accident scenario.

In the evolution of safety thinking, we passed into another era, the "human era" of CRM and LOFT and TEM. We've studied the aspects of the cockpit social gradient, recognized the copilot or pilot not flying as the "pilot monitoring," introduced training efforts to inspire advocacy for all crewmembers, and upgraded the regulatory efforts in certification and operations. In the maintenance area we recognized the need to clearly state the task instructions, work cards, quality control and oversight of critical tasks, and shift turnover procedures, etc. However, the omnipresent "cause" word continued to appear in the aviation safety lexicon and in the thinking associated with our accident investigation process.

Now we have transitioned toward the "organizational era." We are inclined to focus our investigative attention much more broadly, in no small part based on the foundations in Professor James Reason's Model of Accident Causation. We focus not only on the front line actions of flight crews, air traffic controllers, ground engineers, dispatchers, and other support staff, but also on the working conditions, organizational processes, levels of oversight, and the management decisions from airplane design all the way to the final element of delivering the passengers to the airline terminal at their destination.

We are able to gather much more data than in the past, and we are now motivated to attempt to understand the deeper systemic issues associated with an accident. These systemic issues include the management decisions that provide the background for the operational environment. We are influenced by SMS concepts and the overarching safety culture of the organizations involved, and we endeavor to involve a much broader scope than limit our investigation to the specific organization most closely associated with the operator. We look at the manufacturer's design philosophy, concepts of task sharing, checklist construction, and follow through to examine the regulatory process that permits the airplane to go into service. We look at the training programs for crew and ground personnel and the operating company management practices required for their operating certificate. And, of course, we focus on the working environment of all those front line air and ground personnel who may be associated with the accident.

After such an encompassing look at all these aspects, many will argue that it is unreasonable to single out one front line action and form a causal statement, that narrowly focused last act or omission that may be only a very small part of the complete chain of events. This point is well stated in the International Federation of Airline Pilots' Associations submission to the ICAO Accident Investigation Group Divisional Meeting of 2008. The Association reiterated the need to highlight the multiple issues in the accident scenario—in order to achieve the Annex

What Happened and Why?

ISASI PROCEEDINGS 2009

13 goals of corrective actions and safety recommendations to address a broad range of causal issues and to mitigate the associated risks.

Any discussion of the "cause" subject would be incomplete without a search of the opinions of our close ISASI colleagues, and the bibliography of the *ISASI Forum* publications provides a treasure trove of articles on the subject. From the late 1970s to the present, there are 20 "Cause(s)" titles in our ISASI library authored by well-known safety advocates.

In 1979, ISASI member Tom H. Davis wrote an *ISASI Forum* article describing probable cause as a misnomer that detracts from the investigator's role of finding all the causes. He offered the conclusion that "...there is no 'the probable cause,' but only a multitude of probable causes…."

Fellow ISASI member Professor Richard H. Wood, referring to the fundamental accident prevention objective of Annex 13, at the ISASI seminar (Vancouver) in 1988, stated that "The fact is, though, the results of an aircraft accident investigation are used to assess blame whether we like it or not."

Swedish AIB investigator Aage Roed in 1989 wrote, "During my 9 years at the Board of Accident Investigation, I have continuously repeated the mistake of writing one single accident cause in my reports. These cause determinations are often useless in accident prevention work since they do not provide any ideas for accident prevention."

Jerome F. "Jerry" Lederer, president emeritus of the Flight Safety Foundation and recognized throughout the industry as the "father of aviation safety," in 1992 wrote, "Would not the adoption of 'Findings,' 'Significant Factors,' and 'Recommendations' remove the contentiousness now surrounding 'Probable Cause' without detracting from the lessons learned to improve the safety of flight?"

One conclusion can be drawn from the input of some of our colleagues within the air transport industry—those motivated to write about causes. Many persons closely associated with the investigative process uniformly argue that causal statements contribute toward blame and liability, and therefore they opine that such statements should not appear in the final report.

Offering an added perspective, two well-respected contributors to ISASI activities, while condemning the ills of causal statements, found it appropriate to include the expectations of the public in the investigation process. Dr. C.O. Miller's article *Down with Probable Cause* presented at the ISASI seminar (Canberra) in 1991 offers a thorough and encompassing study of the evolution of cause, the pros and cons, and concludes with suggestions on "what can and should be done." Dr. Miller highlights a most important group of consumers (the public), whose interests are frequently overlooked in the causal discussion among those within the air safety investigation community. He offers a point-counterpoint summarized as follows:

Point—The public is used to it (cause) and seems to like it. Counterpoint—Perhaps if the public knew of the difficulties resulting from special emphasis causes, they might change their attitude?

Point—Cause(s) provide a simple answer for the public. Counterpoint—The public seems to thrive on one cause, not a multiplicity of them. Can a well-considered press release overcome this tendency?

Another valuable contribution addressing public interest comes from our former ISASI Forum editor Ira Rimson in an article titled *Investigating Causes* presented at the ISASI seminar (Barcelona) in 1998. His paragraph titled "Customers and accountability" highlights the United States Aviation Disaster Family Assistance Act and the obligation of investigators within the government investigation agency to keep the victims' families and the public informed.

People in modern democratic societies are affected by the "communications moment" of a major air accident. They participate in open government whereby citizens are able to maintain trust in their government through this interaction, and they expect to be informed on such events. The open government features of society embodied by "Freedom of Information initiatives" continue to proliferate in a number of States. A keystone of the trust and confidence in government is the free flow of information. And a national catastrophe such as a major air accident puts this issue in sharp focus with high public expectations directed to the investigation.

The traveling public in most of the developed world (certainly those States represented in the ISASI community) is an informed and interactive group; they read various news media outlets, they blog, they twitter! Many of them are national legislators, political figures, news media representatives, or successful business executives. As a result, they have high interest in aviation, and some of them are the customers of our final reports. They can be an ally or a foe to the air transport industry. They can be an advocate for our investigative process and safety recommendations or, on the contrary, they can lose confidence in the accident investigation authority's ability to provide meaningful information and become adversarial to the industry and to the existing government oversight.

We have seen the demise of airline companies and key government officials replaced as a result of circumstances associated with a major accident. If the public and the other stakeholders outside the close-knit aviation community are kept informed and if they regard our investigative work as credible, they can support our safety objectives. If they think we are withholding information, keeping secrets, and taking sides, unable to call out the truth, they will be our detractors. The same observation can be applied to the press, legislators, and victims' families. If they believe accident investigation authorities are credible, they will advocate for us. Otherwise?

A final report lacking understandable causal factors may lose the confidence of these public customers. Regrettably these stakeholders simply may not be prepared to comprehend and accept the issues of multiple causation, as we in the industry would desire. In the event of a national catastrophe (perhaps an air accident of 50-250 fatalities) public expectations from the official accident investigation and final report will run high, and include all manner of questions about "how and why" this tragedy happened. Accident investigation authorities that provide to the public a final report devoid of causes, or offer convoluted findings and factors, set the stage for a variety of parties, all with vested interests, to step in to pronounce cause(s) as they see fit...to their benefit. Confusion regarding causal factors in a major event provides a perfect setting for tabloid journalism to run amuck.

This somewhat untenable background provides us with an opportunity to compare two recent and well-based initiatives. One is the ICAO Manual of Aircraft Accident and Incident Investigation, Part IV, Reporting, Doc. 9756, published in 2003. The guidance material in this Manual was compiled by some very learned safety practitioners brought together by the ICAO AIG Office. The causal statement is the subject of several pages of guidance, including a table of exemplar wording tailored to indicate how to avoid language of a blame-setting nature that is focused on an individual person. Rather, this guidance focuses on the task not accomplished or the inadequacy of a facility or a program. This guidance is intended to deflect and disassociate causal statements from the connotation of blame. It is quickly evident to a reader that use of this guidance will provide an informative causal statement, yet one that is less attractive to misuse in judicial or administrative actions. An example from the Manual follows:

ISASI PROCEEDINGS 2009

One accident—same cause(s)

– failure of the airport management to identify and correct airport drainage
versus
+ the known and uncorrected lack of runway drainage
– the flight crew's mismanagement of final approach airspeed
versus
+aircraft crossed the threshold 16 knots above V_{ref}
– the flight crew's mismanagement of the thrust reversers
versus
+ the late application of reverse thrust

Another somewhat different initiative has been undertaken by several ICAO Member States. They have promoted national legislative initiatives intended to moderate or eliminate the appearance of "causes" in their final report of accidents. In Australia, the Transport Safety Investigation Act of 2003 (TSI Act) as recently amended directs the Australian Transport Safety Bureau (ATSB) to identify factors that contribute to transport safety matters and communicate/publish a report to the relevant sectors of the transportation industry. The ATSB eliminated the cause word from its investigation reports since 2006. Australian reports contain only "contributing safety factors" to avoid any language grounded in legal liability or legal contributions. New Zealand follows a similar practice. Korea provided a further initiative at the AIG 2008 Divisional Meeting making the point that a final report containing only direct cause factors may omit other deficient safety factors needing correction. Brazil's CENIPA final report on the Sept. 29, 2006, GOL Airlines Boeing 737/EMB-135 BJ Legacy airplane mid-air collision is published with a Paragraph 5 conclusion section listing facts and contributing factors in lieu of any mention of a cause. And the TSB of Canada has for several years used a somewhat different approach to its conclusions using the term "Findings as to Causes and Contributing Factors" in lieu of a specific causal statement.

As a result of the discussions at the AIG 2008 Divisional Meeting, the ICAO secretary general circulated a letter to Member States in May 2009 containing a proposed amendment to Annex 13 to be applicable on Nov. 18, 2010. The proposed amendment includes language to provide for the determination of cause(s) "and/or" contributing factors in a final report. The proposal will affect both the definition of

THE ACCIDENT 'CAUSE' STATEMENT
Is It Beyond Its Time?

an investigation and the format of the final report. Left unanswered is the important task to provide a definition of "contributing factors" in the context of Annex 13. States will be able to use either "causes" or "contributing factors," or both, in the conclusions to the final report. Also, additional States participating in the investigation and entitled to provide accredited representative comments to the draft final report (consultation) will be free to use the and/or option in their response consistent with their national protocols regarding the causal issue. Following these many, many years of discussions about causal factors, the changes proposed by the secretary general are expected to be accepted by a majority of responding states. For the future, guided by national legislation, the introduction or omission of cause(s) will rest with the accident investigation authority of each State.

Summary

Is the accident cause statement beyond its time? After many years of use, and abuse, is it time to omit this traditional step in the Annex 13 investigation process? To review, can the overall objectives of instigating safety actions to reduce or eliminate risk still be accomplished without naming the cause(s) of the accident? Will the statement of cause(s) be missed? If so, by whom, and with what result?

Of course we can meet the objectives of reducing or eliminating risk without providing a causal statement. Simply put, it does not take an accident to provide an opportunity to initiate a safety action or accomplish a formal safety recommendation. In fact, this is what we envision to some degree in the future with the introduction of SMS, continuous monitoring, and proactive and predictive risk reduction programs. However, if desired safety actions or recommendations are preceded by an accident causal statement, tradition may indicate that a causal statement provides value-added emphasis to the justification necessary to overcome resistance and gain positive action on many safety proposals. That value-added emphasis may provide the extra momentum necessary to overcome financial and political obstacles and may outweigh the undesirable effects of causal statements.

Some will argue that we can better meet a wider range of objectives toward reducing or eliminating risk without the causal statement. This premise is based on the fact that a causal statement is self limiting and sharply focused, allowing some/many contributing factors to be dismissed or relegated to less importance—possibly never seeing corrective action until they resurface as causal in another accident. Although well substantiated in select case studies, this deficit can be reduced if the written report offers a continuum of detailed contributing factors.

How can we reduce the misuse of a final report to assess blame? Educating a sensationalist press is a never-ending task; some of our former members seem to enjoy participating in tabloidism. However, ICAO has recognized the importance of editorial style to reduce inappropriate use of the final report and provided guidance in the ICAO Manual of Aircraft Accident Investigation, Part IV, Doc. 9756.

Language should not be of a blame-setting nature but rather focus on functions not performed. Investigators who draft the reports and officials who approve of the final report can make strides toward avoiding misuse if they will follow this guidance. It has been further suggested that to eliminate the word cause within the final report will make it less valuable to those desiring to misuse the report. This may be true in some societies, but one should ask, is it appropriate that the Annex 13 report be altered? Or should the society be better educated on the safety objectives of Annex 13 and should the national law of that society be altered to better reflect those same safety objectives (not to apportion blame or liability)? The most suitable answer is to better educate the judicial officials (and the news media and public) about the overall objectives of the ICAO protocols and encourage national legislation to protect the final report from misuse.

Lastly, a final accident report devoid of any defined causes may prove deficient to an affected community of users. The broad community that is receiving a final report of a major tragedy holds strong expectations that a publicly funded independent investigation will provide a causal statement. Many of these report users (customers) will not be satisfied with a convoluted or oblique statement of causes. If their expectations regarding causes are not met, they can be expected to turn elsewhere for causal answers. This search may produce self-serving and erroneous statements of cause and unintended consequences and may erode the credibility of the investigation and serve to undermine the reputation of the investigation authority.

So after more than 40 years of providing cause(s) in the ICAO final report, we have come to a choice, a fork in the road. The ultimate objective of Annex 13 will remain as always, to promote risk reduction initiatives to make a safe air travel system even safer. However, with recognition of the cultural differences and national legislation of individual States, some accident investigation authorities will continue to recognize the need to fulfill expectations of various interests and provide cause(s) in final reports while other investigation authorities will find it appropriate within the needs of their society to provide a final report listing factors. Both methods will be acceptable in the "and/or" ICAO format. Only time will tell us how the public, legislators, and the professional aviation community will regard these different approaches—and how the credibility of our government air safety investigation process and documentation will be regarded in the future. ◆

MAKING GENERAL AVIATION SAFER

The author shows how accident prevention in general aviation (GA) could be improved by more widespread use of lightweight flight recorders, especially through flight data monitoring, instruction, flight simulation, and leisure activities.

By Philippe Plantin de Hugues, Ph.D., Head of Flight Recorders and Avionics Systems Division, Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile

(This article is adapted with permission from the author's paper entitled Safety Strides Foreseen with Lightweight Flight Recorders for GA *presented at the* ISASI *2009 seminar held in Orlando, Fla., Sept. 14-18, 2009, which carried the theme "Accident Prevention Beyond Investigation." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

Statistics on general aviation (GA) during the last 10 years in Europe and the United States indicate that the number of fatal accidents has not fallen despite innovations related to technological evolutions.

At present, data are often insufficient during investigations, even though low-cost audio, parameter, and video recorders have become available recently for the GA environment. For more than 2 years, the BEA has chaired a working group of 120 specialists from 12 countries that has now defined specifications for lightweight flight recorder systems. Any future regulations applicable to small aircraft under 5.7 tons will reference these specifications. According to EASA, almost 79,000 aircraft under 5.7 tons are active in Europe, and according to GAMA nearly three times as many are active in the United States.

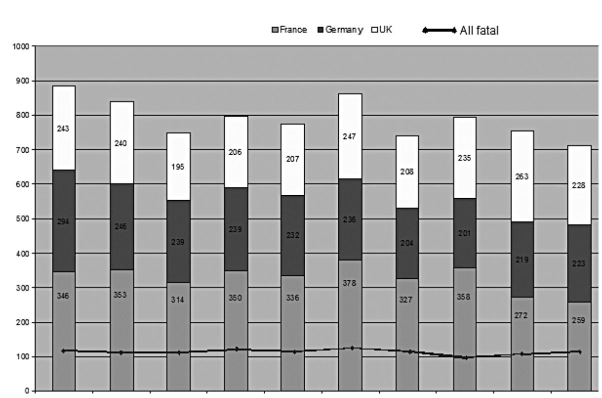

Figure 1. Number of accidents during the last 10 years. (Source: BEA, BFU, and CAA)

The graph (Figure 1) shows the number of accidents, including fatal accidents, in the last 10 years. It is noticeable that fatal accidents have stabilized at around 100 a year. The same regrettable stagnation has happened in the United States.

The graph of fatal accidents in Europe was not easy to develop as a result of different procedures used for entering database information. In order to present validated data, only the annual databases from the three European countries mentioned (France, Germany, the UK) were used. It wasn't possible to distinguish the accidents in relation to the age or the technology of the airplanes. It was, however, apparent that for airplanes defined as "modern" the percentage of accidents was no lower.

As regards France, the analysis of the ECCAIRS database used by the BEA between 2003 and 2007 for aircraft under 5.7 tons (airplanes, helicopters, gliders, micro-lights) shows that for half of the 126 fatal accidents recorded (84 fatalities), the causes were not established with any certainty (causes probable or unknown).

In the majority of events, the only usable flight data for investigative bodies are those that can be read out from onboard computers, such as from a GPS. To download data from electronic cards in damaged computers, the BEA's laboratory has developed some very effective software. This expertise has, for example, allowed 3-D trajectories to be elaborated. Nevertheless, the data are not always sufficient to determine the causes of accidents.

Equipment available on the market

The aeronautical industry has taken proactive steps in the production of low-cost, lightweight flight recorders. The BEA was approached in 2004 and 2005 by pilots and manufacturers to find out which pa-

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Figure 2

rameters would be the most relevant for recordings that could bring the greatest understanding of the causes of accidents. This approach led to the creation of the EUROCAE working group by the BEA on lightweight flight recorders, details of which follow.

There are more than 20 manufacturers around the world, including five in France, that produce flight recorders aimed at general aviation. The more proactive manufacturers consider that improved safety can be achieved by using recorders for flight data monitoring (FDM), maintenance, or even flight management. These recorders weigh just a few hundred grams, and several hundred units are already flying in France. They can record a wide range of data: attitude, position, speed, acceleration, altitude pressure, temperatures, etc. The data can be acquired in several ways according to the airplane's technology and the objective:

- In a standalone manner when the recorder itself has gyroscopic sensors, GPS positioning, or accelerometers.
- From the installation of sensors dedicated to recording. Manufacturers say that it takes one or two man-days to install them.
- Fy recovering all the data passing through the bus installed on more recent aircraft.

These data can be completed by image and sound recordings, which can represent less expensive solutions in the context of an aircraft retrofit. In fact, the analysis of images makes it possible to capture all the information provided to pilots via the airplane's instrument panel.

Some manufacturers even offer image analysis (Figure 2) that makes possible the automatic extraction of parameters linked to the instruments with which the image is recorded. These recordings can capture the airplane parameters as well as the atmosphere in the cockpit and some types of human behavior that can be crucial to understanding accidents.

Investigation using an audio and video recording

Shortly after takeoff on Jan. 6, 2003, at Chambéry Challes the Eaux (France), the DR400 registered F-GGJR with two persons on board stalled and crashed into a hangar 800 meters from the end of Runway 33. The passenger had a video camera and filmed the flight from takeoff until impact (Figure 3).

The camera tape was not badly damaged during the accident, and analysis of the video recording revealed the following:

- Start-up was difficult, then the pilot started the takeoff run.
- The run lasted about 72 seconds over a distance of 600 meters.
- The pilot was holding a mobile phone in his hand from time to time during the takeoff run.

Figure 3

- The takeoff run speed of the airplane was deduced from the visual passage of the white lines (20 meters long and 20 meters between them).
- The value of some parameters shown on the airplane instruments.
- The right wing leading edge had an irregular distortion that could be attributed to an ice deposit.
- After takeoff, the airplane leveled off, then climbed toward about 150/200 feet, followed by a turn on a 300° heading with a low rate of bank.
- The airplane continued more or less in level flight at the same height without giving the impression of gaining speed.
- The loss of control occurred with a sharp roll to the right, associated with a high nose-down attitude.

The spectral analysis of the audio recording on the videotape made it possible to deduce the following:

- The engine RPM.
- The frequency of the wheel (38 centimeters diameter) rotation during the run, and thus a precise figure for the airplane takeoff run speed.

In addition, the following elements were recorded without any specific signal treatment:

- The warnings.
- Speech of those on board.

Thus, based on these elements, the history of the flight could be established precisely and can be listed as follows:

- Start of takeoff run at T=0.
- The takeoff occurred at T + 28 seconds.
- At T + 60 seconds, the engine RPM dropped and stabilized at 2,220 RPM.
- At T + 66.5 seconds, the airplane slowly began to roll and lost altitude.
- At T + 67 seconds, the stall warning sounded.
- At T + 69 seconds, the stall warning sounded again and continued until the

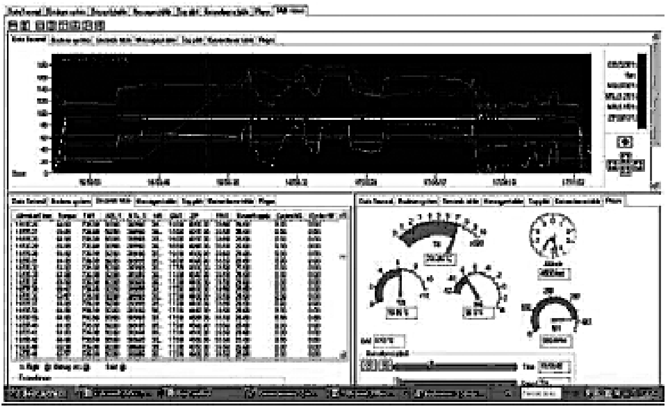


Figure 4

impact with the ground. The airplane had about a 30° bank to the right, 10° nose down, and lost altitude. The airplane was diving at a very steep rate with a roll angle.

- At T + 75 seconds, the airplane struck the ground.

Wreckage examination showed a heavy airplane that was balanced to the aft, with the flaps in the landing position. Fortunately, analysis of the video and audio recordings also made it possible to determine with certainty that with a degraded aerodynamic wing profile, the plane had stalled after a slight reduction in thrust.

The regulations

Since 2006, the ICAO FLIRECP (FLIght RECorder Panel) has worked on improving the flight recorders section of Annex 6. In the final meetings, it was decided to propose fitting lightweight flight recorders to airplanes under 5.7 tons.

These propositions were developed using cost-benefit analysis, with an evaluation of the safety benefits implying an underlying value to human life. This led to comparing the implementation cost with the benefits that could accrue in terms of reductions in accidents, in damage, and deaths avoided rather than in simple economic terms. The new proposition for Annex 6 was sent for consultation to States in July 2009. This document will refer to the EUROCAE ED-155 document described later .

At the same time, thanks to recommendations issued by the AAIB, EASA carried out in 2008 a study entitled "Investigation of the Technical Feasibility and Safety Benefit of a Light Airplane Operational Flight Data Monitoring (FDM) System." Experience gained during many years has shown that FDM can make a continuing improvement in the standard of everyday airplane operations.

The overall aim of this study was to demonstrate the capability of a low-cost flight data monitoring system for single-engine light airplanes. The predetermined goal was that the budget of less than 5.000€ per installed system and 2€ per flight hour direct operating costs (DOC) for post flight data analysis services should not be exceeded.

The conclusion of the study is that

- Flight data monitoring as part of Safety Management Systems (SMS) can improve the safety of light airplane aviation.
- Different types of data must be taken into account: additional sensors, digital sources (regular instrumentation), images, and audio.
- The flight trials showed reasonable results with the use of low-cost sensors so that maneuvers could be indentified clearly.
- It is possible to provide the desired systems for a target price of less than 5,000€ and 2€/hour DOC without the use of crash-proof data storage.
- In all cases, potentially unauthorized misuse by policing parties must be precluded.
- User acceptance is an essential necessity for a purposeful FDM.
- Broad user acceptance would be greatly improved if the system can be used for multiple tasks (e.g., maintenance and training or TBO elongation).
- Compared to a retrofit system for older airplanes (additional sensors required), a modern airplane with only digital systems will facilitate the use of a FDM drastically.

In the continuity of this study, another study has been launched to see the real benefit for the FDM on 1,000 hours of flight for various types of aircraft.

EUROCAE Document ED-155

EUROCAE is an international non-profit European organization. Membership is open to manufacturers and users in Europe of equipment for aeronautics, trade associations, national civil aviation administrations, and non-European organizations. Its work program is principally directed to the preparation of performance specifications and guidance documents for civil aviation equipment for adoption and use at European and worldwide levels. EUROCAE has produced standards used in the certification of avionics and approval of ATM equipment and applications for more than 45 years.

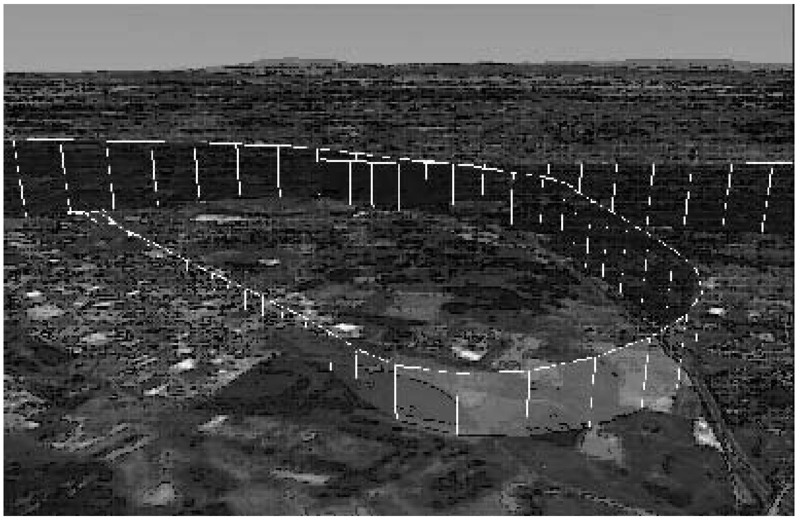
The EUROCAE Document MOPS (Minimum Operation Performance Specification) ED-155 defines the minimum specification to be met for small aircraft required to carry lightweight flight recorders that may record flight data, cockpit audio, images, and datalink messages in a crash-survivable recording medium for the purposes of the investigation of an occurrence (accident or incident).

This document was produced by the EUROCAE Working Group WG-77 with more than 120 members coming from investigation authorities, regulatory bodies, manufacturers, and associations worldwide. The MOPS has a common section for crash and fire survivability, etc., and separate sections for specific functions such as flight data, audio, image, and datalink recording.

The primary objective of this document is to provide specifications to be referenced by a regulatory authority, but it has four other objectives, some of which fall outside the scope of any regulation. We hope to develop a single standard meeting these other objectives

- For the certification authorities who participated in the development of the specifications, the recognized ED-155 will be referenced.
- When a pilot, a company, or an aero club

The need to define SPECIFICATIONS for LIGHTWEIGHT RECORDERS has become OBVIOUS for general aviation safety investigations.



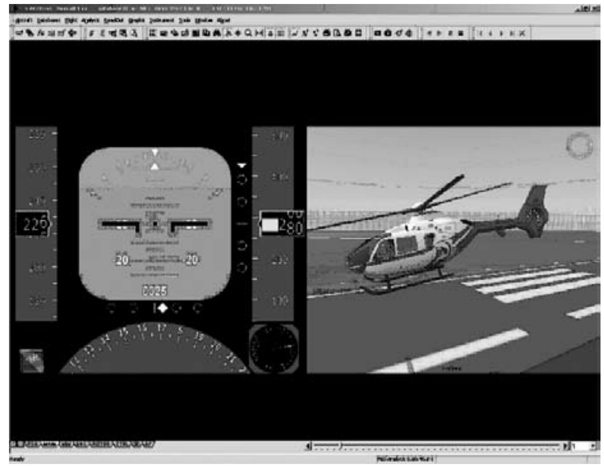


Figure 5 (left) and Figure 6 (right)

wishes to equip an airplane or a helicopter with a lightweight recorder, the recorder's conformity with ED-155 will ensure adherence to a recognized standard.

- For the manufacturer, ED-155 will, for example, allow all the appropriate parameters to be known for the analysis of flights, dedicated to investigations into accidents, as well as defining image resolution. This document must be an aid to development of recorders, even if they are installed without a regulatory requirement.
- A type ED-155 recorder will provide investigators with information that is useful to the understanding of the causes of accidents.

If these four goals are achieved with the increase in lightweight recorders installation, safety will be improved and the unit cost of recorders will fall.

The document also lists the parameters in aircraft data recording systems (ADRS) useful for an investigation, those useful for FDM, the image resolution needed to capture the instruments on the instrument panel of airborne image recording systems (AIRS), and the audio quality to capture the voices of the pilots on cockpit audio recording systems (CARS).

The need to define specifications for lightweight recorders has become obvious for general aviation safety investigations. At the increasingly important global level, changes in the ICAO processes, including funding issues, and a desire to reduce the level of detail contained in ICAO standards lead to a greater reliance on closer relationships with key aviation standards bodies such as EUROCAE and RTCA.

Aviation safety advantages

Accident prevention in GA could be improved by more widespread use of lightweight flight recorders, even outside a mandatory framework especially through flight data monitoring, instruction, flight simulation, and leisure activities. There are a large number of actors in the world of general aviation. If we seek to inform pilots, associations, clubs, and small companies, we need to get each of them involved so that they become aware of the benefits of carrying a recorder.

The advantages for businesses

It is essential to show how a recorder will allow a company to

- optimize maintenance costs,
- optimize potential,
- optimize maintenance of onboard equipment,
- perform systematic flight analysis with automatic detection in which safety thresholds are exceeded (see Figure 4),
- achieve precise billing of flying hours,
- effect simplification of management and administrative structure,
- secure a drop in insurance premiums.

The advantages for training

From a pedagogical perspective, in the context of aero clubs the instructor could help his students returning after a flight with a debriefing (see Figure 5) including

- simple simulation of the training flight with software associated with the recorders,
- the visualization of flight trajectories overlaid on an aeronautical or satellite chart,
- the visualization of flight parameters,
- the study of the students gestures,
- and as much more as can be imagined by instructors.

The advantages for leisure flights

From a leisure perspective, a private pilot might wish to show his family and friends the places that he has flown over. The image recorder (see Figure 6) would allow him to do this with a presentation of an outside view from within the cabin interior. However, the presence of the instrument panel would be vital for any technical investigation.

During first flights, an image recorder with an easily downloadable memory could potentially provide an excellent additional product to customers, as well as being very useful in case of an investigation.

First flights, leisure flights, and instruction flights can all benefit from advances in technology that would be, in parallel, a vital tool for any investigation. The software associated with recorders permits downloading and easy reuse of recorded data. These new tools are thus usable by all pilots.

Some lightweight flight recorder manufacturers have been able to reach agreements with insurers that reduce insurance premiums, which could mean that the initial investment is offset in a few short years.

Conclusion

A new approach must be adopted to highlight the advantages of new data recording systems to all those who operate or use small planes or helicopters. Associations and aero clubs all over the world are the core public to be addressed in this approach.

Over and above its use as a final record to be analyzed by investigators, the recording of a flight could be viewed as a source for optimizing the management of a fleet, for improving pilot training, or as a teaching tool for an instructor. ◆

Examining Accide

The authors illustrate how the accident cost methodology used by the legal profession, namely primary, secondary, and tertiary cost categorization, results in an easily understood relationship between costs and technological remedy, costs and regulatory remedy, and costs and investigative remedy and how it can greatly enhance an aviation accident investigator's ability to frame compelling, well-argued, and fully justified safety recommendations.

By Dr. Simon Mitchell, Aviation Director, RTI Ltd, London, UK, and Visiting Fellow, Cranfield University, UK, and Professor Graham Braithwaite, Director, Cranfield University Safety and Accident Investigation Centre, UK

(This article is adapted with permission from the authors' paper entitled Using the Best Cost Analysis for Effective Safety Recommendations *presented at the ISASI 2009 seminar held in Orlando, Fla., Sept. 14-18, 2009, which carried the theme "Accident Prevention Beyond Investigation." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

Accident investigators play a key role in improving the safety of the air transport industry through painstaking analysis of serious incidents and accidents. Myriad skills are exercised by investigators in their thorough and impartial collection of evidence, analysis of it, and preparation of final reports. Yet as those who work within the independence advocated by ICAO Annex 13 know all too well, poorly prepared recommendations may mean that the painful lessons of an occurrence are not learned. Misdirected, impractical, or ambiguous recommendations may provide an excuse for inaction by an air transport system that is unconvinced by its merit. Careful analysis of recommendations published by many ICAO State investigation reports reveals the difficulty most investigators find in preparing them.

The research presented in this article is concerned with using cost information about accidents to aid decision-makers who seek to avoid or mitigate future costs—in other words, to properly assess the value of proposed safety improvements. The most appropriate analogy to this is management accounting (also known as managerial accounting), which is concerned with providing timely, accurate, and relevant information to those charged with making decisions that affect the financial well-being of an organization. The value of a management accounting system will be assessed on

- Whether the information provided is received in good time to make a balanced judgment, as clearly any information received after a deadline to make the decision is just another cost.
- Whether the information provided clearly identifies those factors (cost drivers) that will be affected by the decision in hand and does not become confused by mixing other cost drivers that will remain unaffected. Related to this is whether the information provided guides decision-makers effectively toward factors most requiring attention.
- Whether the means of measurement is valid, consistent, and reliable.

ICAO guidance

ICAO has published useful guidance on collecting and analyzing accident cost information, most notably in the first edition of Doc. 9859, "*Safety Management Manual*" (2006). Paragraph 1.3.2 underscores the value of understanding the true cost of accidents rather than relying on the safety blanket of insurance: Accidents (and incidents) cost money. Although purchasing "insurance" can spread the costs of an accident over time, accidents make bad business sense. While insurance may cover specified risks, there are many uninsured costs. In addition, there are less tangible (but no less important) costs such as the

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Professor Graham Braithwaite *is the head of the Department of Air Transport and director of the Safety and Accident Investigation Centre at Cranfield University. He holds a Ph.D. from Loughborough University in safety management and is responsible for the aircraft accident investigation courses that run at Cranfield in collaboration with the UK Air Accidents Investigation Branch.*

ent Cost Analysis

COST ITEM	ICAO	CALABRESI
Hull Damage	Direct	Primary
Medical Treatment	Direct	Primary
Property Damage	Direct	Primary
Loss of Business	Indirect	Economic Loss*
Damage to Reputation	Indirect	Economic Loss*
Loss of Use of Equipment	Indirect	Primary
Loss of Staff Productivity	Indirect	Primary
Investigation and Clean-up	Indirect	Tertiary
Insurance Deductibles	Indirect	Secondary
Legal Action	Indirect	Tertiary
Compensation and Damage Claims	Indirect	Secondary and Tertiary
Fines and Citations	Indirect	Primary and Tertiary

*Note: The addition of a classification for "Economic Losses" is a contribution to the system made by Steven Shavell (1987).

Table 1: Accident Cost Classification

loss of confidence of the travelling public. An understanding of the total costs of an accident is fundamental to understanding the economics of safety. (ICAO, 2006)

Acknowledging that air transport has developed to be predominantly about businesses rather than the social provision of transport, ICAO also recognizes that viability is not ensured. With competition from high-speed rail, increased car ownership, and alternatives such as video conferencing, aviation should be clear of one of the advantages that it has long enjoyed—its safety performance. However, as ICAO notes, the industry needs to take care of the customer's perceptions of safety.

Paragraph 1.3.3 The air transportation industry's future viability may well be predicated on its ability to sustain the public's perceived safety while travelling. The management of safety is therefore a prerequisite for a sustainable aviation business.

In author Mitchell's doctoral thesis, the economics of safety were examined using the case study of North Sea passenger helicopter operations. Cost analysis of a fatal helicopter accident revealed not only how little cost data are collated following an occurrence, but also once a thorough analysis had been completed, how expensive an accident really is once all of the costs are considered. It was in developing the cost model that the following methodology was reviewed and adopted.

Alternative cost analysis system

When it comes to assessing cost information, the ICAO guidance (along with that from other regulatory bodies) is useful but not optimal. An alternative system is one that has been widely adopted by the legal profession for analyzing the costs of accidents, described in the Hon. Guido Calabresi's seminal work *The Costs of Accidents* (1970). The author proposes a framework of analysis that clearly apportions costs according to the interests of the stakeholder most concerned.

A summary of ICAO's system and the comparison with Calabresi's works is shown in Table 1.

While the list of cost items shown is obviously not exhaustive, it is sufficiently indicative and also mirrors the list in the ICAO *Safety Management Manual* (2006), Section 4.8, Cost Considerations.

A working definition of direct costs are those items for which it may be possible to get insurance coverage, and indirect costs being those costs outside any insurance coverage. A more detailed set of definitions is given in *Safety Management Manual* (2nd Edition, 2008), Chapter 5, Paragraphs 5.3.8-5.3.9. However, for our purposes, we will assume that readers are familiar with applying this direct/indirect cost classification system that has been endorsed by ICAO and other regulatory bodies for some time. From here on, the objective will be to summarize the principles of the alternative system and highlight the key advantages to be gained.

It is important to recognize that the definition and priority given to any cost will change according to your viewpoint; and in the case of aircraft accidents, these viewpoints (and related stakeholders) are often in conflict. The air transport industry has many stakeholders, but for the purposes of accident cost (and associated safety cost) analysis, they can be reduced to three broad groups, identifiable by the primary interest of members.

Stakeholders

According to Calabresi and Shavell, there are three identifiable categories of stakeholder. The "industry" clearly forms one major group, whose members will include operators, maintenance organizations, and manufacturers. "Society" forms the second, made up of both individual protagonists, community groups, and the wider population. The third group is "administration," comprised of executive, legislative, and judicial authorities charged with the duties of ensuring long-term social efficiency and justice.

Having recognized these differing and sometimes competing interests, Calabresi found that greatly improved analysis of accident cost reduction strategies would result once a clear set of goals (justice and cost reduction) and associated sub-goals (e.g., reducing administrative costs) are first identified. Underpinning the whole of this framework of analysis is the concept of classifying costs into three groups: 1) primary, 2) secondary, and 3) tertiary. It is worth noting that it is this third classifica-

CATEGORY	ACCIDENT COST	SAFETY RECOMMENDATION	KEY STAKEHOLDER
PRIMARY	Fixed asset loss/damage, human capital loss/damage	Improved reliability measured against probability of failure	Industry (operators, service providers, and OEMs)
SECONDARY	Market instability, compensation	Reputational measures targeted to enhance trust and confidence	Legislative branches of government
TERTIARY	Investigation costs, regulation, court administration	Tools to minimize or resolve uncertainty and ambiguity, enhance social efficiency	Executive branches of government and judiciary
ECONOMIC LOSS	Specific business issue risks	Corporate governance	Shareholders

Figure 1. Accident cost/safety recommendation framework.

tion of "tertiary" costs that is the source of most advantages of the Calabresi system over the direct/indirect system.

Primary costs of accidents—These are the most obvious and directly related group of costs. By definition, an accident is an unplanned, unintended event that results in harm or damage, and therefore losses (which result in costs). These costs range from damage to equipment to damage to property and/or infrastructure and may culminate in injuries to people. Equipment needs to be repaired or replaced; damaged property needs to be secured, repaired, or rebuilt; infrastructure needs to be stabilized and reinstated; injuries to victims require medical attention.

Secondary costs of accidents—Secondary costs are the "societal costs" arising from accidents. These costs include the various compensations to victims and/or the families of victims. It also includes activities that are aimed at managing long-term psychological and related social impacts, through counseling, government, and community support.

Tertiary costs of accidents—Coping with accidents involves organizing the resources of multiple parties and organizations and arbitrating competing interests. This gives rise to a set of costs concerned with administrating the system, and, in the case of aviation accidents, includes such items as accident investigation, safety regulation, and legal proceedings.

Economic loss

The issue of "economic loss," as distinct from other accident costs, is a way to highlight particular circumstances of a situation that will not be generally true for others, or for consideration by the air transport system as a whole. Inclusion of these items as costs might distort or otherwise impose a bias on the decision-making process. An example of this would be an individual operator's loss of business where another operator picks up that business. In this case, the industry, per se, has not experienced a cost, just that individual operator. On the other hand, if that business is lost altogether, then that is a cost to the industry. Another example might be when there is an accident causing injury to a very high-net-worth passenger, potentially owning assets worth many billions of dollars. This may well justify extraordinary measures but is clearly a very particular and specific set of circumstances rather than a matter for industry stakeholders.

Another advantage of Calabresi's accident cost categorization system is that it becomes easier to identify the interaction between different actions and any unintended consequences that might result. An initiative solely targeted at one category of cost will not necessarily be sympathetic with another, and so the overall effect may be to actually increase overall accident costs.

Directionality

An appreciation of the concept of directionality is probably the strongest argument for adopting this framework of cost analysis over any other. The closest analogy is an understanding of the interaction between zero lift drag and lift induced drag on total drag in aerodynamics—where reductions in one through an increase in speed may produce an overall advantage in total drag up until an optimal point and, thereafter, be negated by increases in the other to create an overall detrimental impact on total drag.

In a similar fashion, it is important to note that reducing any one group of costs will not always result in an overall reduction in the costs of accidents. In some circumstances, targeting the primary costs, for example, will result in an increase in secondary costs. If, for example, excluding all aircraft that were not multi-jet-powered reduced the frequency of accidents, this might also result in costs to society (e.g., severely restricting "feeder"-type airlines). Similarly, if all accidents were perfectly compensated (secondary cost reduction), there would be reduced incentives to avoid accidents (primary costs).

Calabresi in his *The Costs of Accidents* (1970) writes *"It should be noted in advance that these sub-goals* [primary/secondary/tertiary cost reduction] *are not fully consistent with each other.... We cannot have more than a certain amount of reduction in one category without forgoing some reduction in the other, just as we cannot reduce all accident costs beyond a certain point without incurring costs in achieving the reduction that are greater than the reduction is worth. Our aim must be to find the best combination of primary, secondary, and tertiary cost reduction taking into account what must be given up to achieve that reduction."*

Application

While it is not always obvious where distinctions should be made between these categorizations, the process of classification does direct the attention of the relevant stakeholders toward the relevant issues of concern in their areas of control most effectively. In this way, whether or not absolute consistency is achieved in the classification process, the overall objective will be largely achieved.

Diagrammatically the system can be summarized as illustrated in Figure 1.

The important thing to recognize is that not every objective concerned with maintaining a stable and sustainable air transport industry is concerned with the probability of failure and an associated justification predicated on the expected value of saving life (even if that is the ultimate objective). Therefore, it is important to separate the various goals and sub-goals in order to match the safety recommendation to the appropriate costs. Consequently, the validity of any associated cost-benefit analysis will be greatly strengthened, without resource to emotive reasoning.

Some illustrative examples

1. Past accidents in which primary factors are of preeminent concern.

A safety recommendation concerned with primary cost will be fully justifiable on the existing basis of cost-benefit analysis—namely, probability of failure and expected cost of damages or loss of life. There are many examples of accident investigation that highlighted some previously unknown failure mode or issue of reliability. Two recent cases are

- Boeing 777, G-YMMM, Jan. 17, 2008, London Heathrow, with new knowledge about the formation of ice reliability in the fuel system.
- AS332 L2, Super Puma, G-REDL, Apr. 1, 2009, with a focus on the reliability of the main gearbox.

2. Past accidents in which secondary factors are of preeminent concern.

A safety recommendation concerned with addressing a secondary cost might well be justified on the basis of the expected loss in passenger demand (or a scenario analysis based on a range of values) or the necessary ticket price changes (temporary or permanent) to maintain yields. It should be recognized that these secondary (social) factors are the ones with real potential to place the industry into crisis. Examples of accident investigation that have significant market potential often involve some major political event, most notably

- The terrorist bombing of Boeing 747, Pan Am 103, Dec. 21, 1988, Lockerbie.
- The 9/11 attacks in New York.

However, it is also possible to see these "secondary" factors evident in less cataclysmic situations as well, for example,

- AAIB, Special Bulletin, S3/2009, Eurocopter EC225, G-REDU, Feb. 18, 2009: *"Because of the importance of helicopter operations in support of the offshore oil and gas industry, it is considered appropriate to disseminate the results of the initial investigation as soon as possible. No analysis of the facts has been attempted."*

3. Past accidents in which tertiary factors are of preeminent concern.

A safety recommendation concerned with addressing a tertiary cost might well be justified on the investigation costs saved should better quality information be available, or avoiding damaging public disagreement and resolving contentious differences of opinion efficiently. Additionally, it will be a justification made against system-based costs (recognizing the agents of State as legitimate stakeholders, with specific roles and with financial interests) rather than attempting to justify cost-benefit on the level of each and every individual operator.

Probably the most pressing tertiary factor for accident investigation is concerned with flight data recorders (FDR). There have been numerous accidents that cannot be resolved satisfactorily because of the lack of adequate data, to the extent that the International Helicopter Safety Team (IHST) has made wider use of FDR a keystone of its strategy to reduce helicopter accidents by 80% by 2016 [see *Forum*, January-March, page 16]. However, it is evident that to demonstrate the full financial value of this initiative, the issue needs to be considered at a system level rather that at an individual operator level. Possibly the highest profile examples that illustrate the potential value of proper allocation of resources to tertiary factors (in practical terms, aids to investigation) are

- Boeing 737, US Air 427, Sept. 8, 1994, Pennsylvania, where the investigation was frustrated by the lack of data concerning the loss of control.
- Boeing 747, TWA 800, July 17, 1996, Atlantic Ocean near New York, resulting in a highly complex and costly investigation process because of a lack of objective data.

Summary

In the face of any accident aftermath, there is a clear and recognized need to fulfill obligations and responsibilities toward multiple parties, each with its own set of priorities and goals. The recommendation remains the most powerful weapon in the arsenal of the investigator but should be used wisely. Although this should not be a primary driver in deciding whether to make a recommendation, understanding the cost implication may assist investigators in directing them. This is particularly important where costs are less visible, as is often the case with secondary and tertiary costs.

A cost categorization and classification system that best matches these goals and priorities will likely aid more socially efficient decision-making than alternative systems. The authors have compared these two systems in great detail and are of the opinion that the accident cost classification system based on Calabresi's *The Costs of Accidents* (1970), modified by Shavell's *Economic Analysis of Accidents Law* (1987), is superior in this regard. Due to the principles on which the framework is founded, it encourages the accident investigator or safety analyst to represent the problem from different viewpoints. In this way, it is also a very useful aid for structuring the whole safety analysis along logical pathways, without adding any significant complexity for the analyst. It is for these reasons of effectiveness, clarity, and ease of use that accident investigators should give serious consideration to adopting this technique when identifying and framing safety recommendations. ◆

A REVIEW OF FLY-BY-WIRE ACCIDENTS

In this history of fly-by-wire (FBW) airplanes, the authors place an emphasis on the certification requirements found in Part 25. They examine the service history of civil FBW airplanes, using several databases for FBW accidents and serious incidents, excluding those with no flight control involvement. They use the term "incident" to describe "accidents and serious incident" events.

By Dr. R.L. (Dick) Newman and A.A. (Tony) Lambregts,
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(This article is adapted with permission from the authors' paper entitled A Review of Fly-by-Wire Accidents *presented at the ISASI 2009 seminar held in Orlando, Fla., Sept. 14-18, 2009, which carried the theme "Accident Prevention Beyond Investigation." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

In October 2008, Qantas Flight 072 experienced a flight control malfunction flying between Singapore and Perth. The airplane pitched over abruptly seriously injuring a total of 14 passengers and cabin crew. The flight diverted to an Australian Air Force base, and the injured were flown by helicopter to the hospital.

This accident gave impetus to efforts to review the certification requirements dealing with fly-by-wire (FBW) flight controls. The certifying authorities have been certifying FBW airplanes using special conditions to augment the traditional airworthiness requirements for flight controls in areas where these existing requirements are inappropriate or inadequate.

Background

FBW is the description of airplane flight controls in which there is no direct mechanical connection between the pilot's stick and rudder and the flight control surfaces, such as the ailerons or elevators. Most, if not all, new transport airplanes have FBW flight control systems. For the manufacturers, elimination of the cable and pulleys means a significant weight savings, which translates to increased payload or fuel savings. It also greatly reduces the manufacturing and maintenance manpower requirements. Any airplane mechanic will tell you that control rigging can be time consuming.

The first civil transport with FBW was the Concorde, which entered service in 1976. Control rigging was the driving issue since the fuselage grew by some 10-12 inches during supersonic cruise.

Modern FBW flight controls use onboard digital computers to modify the pilot's control inputs before sending the signal to the actual control surfaces. The first operational use of FBW flight controls was on the military F-16 fighter. The flight control computers in a FBW airplane design can be used to augment the airplane's stability, handling qualities, and maneuverability to the desired level, when the operational center of gravity of the airplane is moved aft to reduce airplane drag. In transport airplanes, such as the Airbus A320 or Boeing 777, this

Abbreviations

ADIRU—Air data inertial reference unit
ASRS—Aviation Safety Reporting System (NASA)
FBW—Fly-by-wire
FCS—Flight control system
FL—Flight level
MEL—Minimum equipment list
M_{MO}—Maximum operating Mach
PF—Pilot flying
PIO—Pilot induced oscillation
PNF—Pilot not flying
TCAS—Traffic Advisory and Collision Avoidance System ◆

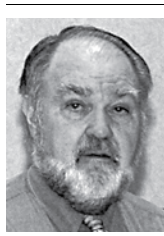

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Photo not available

Tony Lambregts *is the FAA's chief scientific and technical advisor for advanced control systems. He has more than 40 years of experience, 29 with the Boeing Company, where he worked on a wide variety of production and research projects. Prior to joining the FAA, he worked for a year with Fokker Aircraft on fly-by-wire design and taught at the Delft University of Technology.*

Table I: Civil Transport FBW Models

Manufacturer	Certified Models	Proposed Models
Airbus	A320, A330, A340, A380	A350
Boeing	777	787
Bombardier		C-series
Dassault	7X	SMS
Embraer	E170, E190	
Gulfstream		G-VI, G-250
Ilyushin	Il-96	
Misubishi		RJ
Sukhoi		SSJ-100
Tupolev	Tu-204	
Models	10 Current	8 Proposed

Table II: Accidents Caused by FBW Systems

Date	Model	Location	Phase	Description	Injuries	Damage
02/07/01	A320	LEBB	Landing	Abrupt Maneuver	1 serious 25 minor	Write off
03/17/01	A320	KDTW	Rotation	Pilot Induced Oscillation	3 minor	Substantial
10/07/08	A330	YPLM	Cruise	Uncommanded Pitch	14 Serious	Minor

Table III: FBW Incidents in Civil Aircraft

Model	Accidents	Incidents	Total	Rate*
A320	7	13	20	0.30
A330/340	2	2	4	0.26
B-777	0	2	2	0.12
E170/190	0	1	1	0.16
All Others	0	0	0	--
Total	9	18	27	

* Rate is events per million flight hours.

Table IV: Types of FBW Incidents

Type of Incident	Number	Comments
Uncommanded pitch/bank	11	8 Pitch, 3 Bank
Abrupt maneuver	6	Dual control input
Pilot Induced Oscillation	4	
Collision with terrain/obstacle	3	1-Dual control input 2-Envelope protection misused
FCS mode reversion	2	
Tailstrike	1	
Total	27	

can mean burning less fuel or being able to carry more payload.

In addition, the flight control system can be designed to make the airplane's handling qualities appear the same to the pilot across the range of speed, altitude, and aircraft loading. Different airplanes can be designed to fly with virtually identical handling qualities, thus reducing pilot training costs.

Most FBW flight control system designs also include flight envelope protection features. If present, envelope protection can help prevent the pilot from reaching unsafe flight conditions, such as stalling, overspeeding, overstressing, or overbanking the airplane. As one NASA test pilot said, "This results in carefree handling." In other words, with full authority envelope protection, you just fly the airplane and don't worry about losing control.

Certification requirements for airplane flight controls were developed for traditional mechanical systems. They have not been updated to cover FBW designs. The certification rules still speak of stick-and-rudder motion and forces in terms of direct mechanical systems. None of the current transport FBW airplane designs meet all of the Part 25 requirements. All models—Airbus, Boeing, Dassault, and Embraer—have employed special conditions for the flight control system.

There are currently 10 civil airplane designs with FBW flight controls. These include designs with full stability augmentation, such as the Airbus or Boeing designs, and simpler designs without stability augmentation, such as the Embraer designs. Envelope protection designs range from full authority (Airbus) through limited authority (Boeing) to minimal envelope protection (Embraer). Table I lists the current and proposed civil airplane FBW aircraft. The next section outlines the methodology used to examine the service history. (See Table 1.)

Method

One of the problems with examining safety problems with extremely safe systems is the lack of many examples. We found only three accidents caused by FBW systems (shown in Table II).

With such systems, one cannot examine accidents but must search for precursors. Therefore, we reviewed the service history of civil FBW airplanes, using several databases for FBW accidents and serious incidents. The databases used were the U.S., British, Australian, and Canadian databases. We also used two private databases: the Aviation Safety Network and Flight Simulation Systems databases. Once the event was identified, we examined publicly available information, such as the accident report from the investigating agency. We did not include anonymous reports, such as the NASA ASRS because of the inability to verify information.

Flight test reports were not included for several reasons. It is difficult to obtain reliable data, and the data may not be releasable. Further, the aircraft may not be typical of the in-service configuration. Military safety data were not used for the same reasons. In addition, many military aircraft designs and missions are not representative of civil aircraft.

We grouped airplanes using virtually identical FBW control systems, such as the A330/340 and E170/190. Only airplanes in line operations were considered (test flights were excluded). These incidents were manually reviewed to exclude those with no flight control involvement. Secondary flight controls (i.e., flaps) were not considered. Individual examination of each record was used to cull those with no FBW involvement.

Results

We found 29 accidents and serious incidents involving FBW systems. It must be emphasized that these accidents and incidents involved FBW, not necessarily that FBW was the cause. In fact, in one case, FBW prevented an incident from being catastrophic. Table A (see Appendix, page 22) lists the incidents obtained from this review. Table III summarizes the data.

The principal types of FBW incidents are uncommanded pitch or bank, abrupt maneuver, or pilot induced oscillations (PIO) accounting for 22 of the 27 incidents. There were three collision with terrain accidents. These were not caused by FBW, merely influenced by the system design choices. Two incidents *(cases a and b in Table A)* were caused by the pilot apparently relying on envelope protection to provide terrain clearance. The third incident *(case x)* was apparently caused by spatial disorientation, but was compounded by conflicting control inputs from the two sidesticks.

There were three reported instances

ABRUPT MANEUVERS: The issue of dual control inputs should be studied to determine if simple summing of the pilot inputs is the best solution for designs using sidesticks with passive feel forces.

of the flight controls dropping back into alternate or direct law *(cases n and v)*—relatively minor events. However, they are included because of the potential consequences.

Uncommanded pitch/bank: The predominant causes were specific component failures (flight control electronics or incorrect wiring) often coupled with design errors in flight control software implementation. Fault detection and isolation design errors seem to be a major contributor as well. Many of these involved dispatch with known bad components and subsequent mishandling of an additional failure. Table V summarizes the factors.

Cockpit ergonomics (sidestick) factors are interesting. In one incident *(case y)*, the first officer (PNF) unintentionally depressed the takeover button on his sidestick while the captain was flaring for landing, causing a hard landing. In another incident *(case n)*, the captain's sidestick was wired backwards laterally. The airplane was about to drag a wingtip just after liftoff, and the first officer (PNF) took over, preventing a catastrophic accident.

Abrupt maneuver: These are caused by both pilots applying inputs to the sidestick on an Airbus-type FBW design. When both pilots make inputs, the two inputs are summed, not averaged, to form the output control action. These incidents typically occur when one pilot (PF) is responding to an event, such as a TCAS resolution advisory (RA), and the other pilot (PNF) gets on the control to help. They also occur when one pilot follows through during a landing flare. Usually, it is the captain who adds his control input to the first officer's. Table VI summarizes the factors in abrupt maneuver incidents.

Pilot induced oscillation: These incidents occur when the aircraft responses that the pilot is trying to control get out of phase with the pilot's control input. While this happens in non-FBW airplanes, the added lag of the digital computers and the high dynamic amplitude of the digital signals can saturate the control surface actuator rate or displacement authority without pilot awareness, a particular problem with digital FBW airplanes. In two instances, ice accretion on unprotected flaps affecting the aircraft response was a factor *(cases r and s)*. Table VII summarizes the factors in PIO incidents.

Table V. Factors in 11 Uncommanded Pitch or Bank Incidents

Cause of Incident	Number	Case In Table A	Comments
Flight Control Electronics	4	(e) (f) (g) (n)	
Flight Control Software Implementation	3	(k) (q) (w)	
Sensor Error Detection and Isolation	3	(q) (w) (aa)	2 Sensor, 1 Electrical
System Annunciations	3	(f) (w) (aa)	Multiple Warnings
Cockpit Ergonomics	2	(n) (y)	Sidestick Issues
Envelope Protection Implementation	2	(k) (aa)	
Maintenance Error	2	(c) (n)	
Dual Control Input	1	(y)	
Flight Control Mode Reversion	1	(c)	
Inadvertent Control Input	1	(y)	
Reversed Controls	1	(n)	Maintenance Error
Undetermined	1	(z)	

Pilot misuse of envelope protection: Early in the service of FBW transports, there were two accidents in which it appears that the crew used the envelope protection inappropriately. At the time, many airline instructors were pointing out the features of envelope protection and may have led pilots to either become complacent or actually use the system to command a go-around. These incidents do not reflect on the FBW systems as much as on crew training *(cases a and b)*.

Multiple warnings: In many of these incidents, the crew was presented with multiple failure/fault indications. One report states there was "no recognizable failure" *(case p)*. In addition to the triggering failure/fault, there are cascading annunciations, making the crew's job in troubleshooting difficult *(cases f, p, v, w, and aa)*.

Representative incidents

Space does not permit a complete review of all FBW incidents. The following seven incidents are representative of the list:

A340 abrupt maneuver: On June 21, 1996, an A340 was departing Dallas-Fort Worth. During the climb at 13,800 ft, a TCAS resolution advisory was received. The first officer (PF) responded. The captain (PNF) also responded. This resulted in accelerations in the aft galley of +2.3g, changing to -0.8g. Four flight attendants received serious injuries *(case h)*.

A340 pitch up: On Oct. 2, 2000, an A340 was cruising at FL360 over the North Atlantic in turbulence. A longitudinal gust caused an airspeed increase to Mach 0.882 (M_{MO}+0.02), which disconnected the autopilot. The autothrottle also disengaged and the pilot reduced power to idle, apparently to prevent another overspeed. Subsequently the airspeed fell off sharply and the angle of attack reached Alpha-*prot*, which engaged alpha protection. In alpha protection, the sidestick commands alpha directly. With no pilot stick input, angle of attack is held to Alpha-*prot*. At some point, power was advanced to take off power, either by the flight crew or possibly because Alpha-*floor* was triggered. When alpha reaches Alpha-*floor*, the power is automatically advanced to takeoff power. The airplane pitched up and zoomed to FL384. To disengage the Alpha-prot mode, the flight crew must command a nose-down stick, which the crew eventually did, to return the airplane to the assigned flight level. The result was a near miss with an A330 at FL370 *(case k)*.

A320 landing accident: On Feb. 7, 2001, an A320 was attempting to land at Bilbao when it encountered strong vertical gusts. The crew attempted to go around, but the alpha protection logic was triggered by a high angle-of-attack rate and the dual control input by both pilots. The result was a hard landing, which damaged the airplane beyond repair. Subsequently the alpha protection engage logic was modified *(case l)*.

"Backwards" sidestick: On March 20, 2001, an A320 rolled left at liftoff. The captain (PF) compensated with right stick input. The left roll increased. The first officer instinctively took control. The airplane returned safely to Frankfurt. It was the first flight following maintenance in which one of the two elevator aileron computers was replaced. During this replacement, a connector pin was bent and the connector replaced. Two pairs of wires were reversed. In effect, the captain's sidestick was wired backwards. The independent sidesticks allowed the first officer to fly the airplane safely *(case h)*.

Dispatch with inoperative ADIRU: On Aug. 9, 2001, an A319 had an apparent ADIRU-1 failure. After landing at an outstation with no spare parts, the Nos. 1 and 3 ADIRUs were exchanged. The minimum equipment list (MEL) permits dispatch with an inoperative ADIRU-3, but not with either of the others inoperative. ADIRU-3 was rendered inoperative per the MEL. During the subsequent leg, there were multiple failures and warnings. The report describes the symptoms as having no "recognizable failure." The flight controls switched to alternate law and then to direct law when the gear was extended. The fault was found to be in the pitot tube, not in any of the ADIRUs. Had all three ADIRUs been operative, voting would have detected the error as it did during the previous flight *(case p)*.

Pitch up over Indian Ocean: On Aug. 1, 2005, a B-777 crew received erroneous airspeed and sideslip information during climb. At FL380, simultaneous overspeed and stall warnings occurred, and the autopilot disengaged. This was followed by a pitch up to FL410. In June 2001, accelerometer No. 5 had failed with the flight control system ignoring its output. In the intervening 4 years, the flight controls continued to ignore this latent failure until a second failure occurred at which point the system began to use the faulty accelerometer No. 5 again. As a result of this incident, the failure detection and isolation software was modified to prevent the use of known bad sensors *(case w)*.

Pitch down over Indian Ocean: On Oct. 7, 2008, an A330 autopilot disconnected during cruise with multiple failure indications. While the crew was troubleshooting, the aircraft abruptly pitched down at -0.8g. There was a second pitch down at +0.2g. ADIRU-1 had many spikes in the output data stream and had flagged its output as invalid. Both pitch downs were associated with angle-of-attack spikes to more than 50 degrees alpha. The flight diverted to an air force base. Twelve serious injuries occurred *(case aa)*.

Table VI. Factors in Six Abrupt Maneuver Incidents

Cause of Incident	Number	Case in Table A	Comments
Dual Control Input	6	(h) (i) (l) (o) (t) (u)	
Crew Training	1	(h)	TCAS Maneuver
Envelope Protection Implementation	1	(l)	

Table VII. Factors in Four Pilot-Induced Oscillation Incidents

Cause of Incident	Number	Case in Table A	Comments
Flight Control Gains	3	(d) (r) (s)	
Contaminated Airfoil	2	(r) (s)	Ice on Flaps
Rate Limiting	1	(m)	During Takeoff

Conclusions

The three main types of FBW incidents, uncommanded pitch/bank, abrupt maneuvers, and pilot induced oscillations have different causes.

Uncommanded pitch/bank: To address these events, improvements in system fault detection and isolation are required, particularly for second failures of the same kind and combinations of different types of failures. It is unlikely that we can achieve the requisite reliability without better fault management. At the same time, more attention should be paid to the effect of dispatch with faulty or inoperative system components (allowed by MEL) on the probability of successfully coping with subsequent additional failures (e.g., correct handling of a second failure).

Also there have been a number of incidents and accidents related to envelope protection functions design in which the envelope protection activated due to deficient engage logic design or faulty information fed into the envelope protection function, causing an undesired sharp "pushover," as appears to have recently happened in the Qantas accident mentioned at the beginning of this article. Envelope protection designs in which the envelope protection function mode change latches and remains in effect after the threat of airplane departure from the safe flight envelope has passed and which require flight crew action to restore the normal flight modes are not satisfactory and possibly unsafe *(cases h and l)*. This area will require research to establish satisfactory envelope protection system functional and design safety requirements for certification.

Abrupt maneuvers: The issue of dual control inputs should be studied to determine if simple summing of the pilot inputs is the best solution for designs using sidesticks with passive feel forces. This will require some research and careful assessment of the consequences of dual inputs. At this

We must not forget that overall FBW and envelope protection have prevented accidents and saved lives. In the past 15 years, there have been 27 stall accidents in commercial transport operations with 848 fatalities—*not one was a FBW airplane.*

time, however, we are reluctant to recommend any alternative to simple summing of the pilot inputs in view of the incident at Frankfurt *(case n)*.

More research is also needed to establish sidestick safety requirements related to

- stick maneuver command sensitivity,
- the scheduling of the maneuver command authority for large stick deflections appropriate to the flight condition and,
- harmonization between the displacement maneuver commands and the required deflection forces.

Similar issues with respect to FBW rudder control system designs also need to be addressed.

Pilot induced oscillations: Finally, PIOs will continue to be an issue. Current flight test evaluation is addressing this by requiring evaluation in those areas where PIO is likely. Various prevention approaches have been proposed to develop system design attributes to reduce susceptibility to PIO or to detect PIO and change gains accordingly.

Appendix

Table A: Accident Listing Civil FBW in Service Incidents

Case	Date	Model	Registration	Where	Flight Phase	Description
(a)	26Jun88	A320	F-GFKC	LFGB	Manuevering	Collision with Terrain
(b)	14Feb90	A320	VT-EPN	VOBG	Landing	Collision with Terrain
(c)	26Aug93	A320	G-KMAM	EGKK	Initial Climb	Uncommanded Bank
(d)	27Apr95	A320	N-331NW	KDCA	Approach	Pilot Induced Oscillation (PIO)
(e)	28Apr95	A320	N-331NW	KMSP	Climb	Uncommanded Bank
(f)	18Mar96	A320	N-340NW	KDTW	Cruise	Uncommanded Pitch
(g)	14Jun96	A320	N-347NW	KBOS	Climb	Uncommanded Pitch
(h)	21Jun96	A340	D-AIBE	KDFW	Climb	Abrupt Maneuver
(i)	14Aug98	A320	G-MIDA	EIDW	Landing Flare	Abrupt Maneuver
(j)	5Nov99	B-777	N-784UA	EGLL	Rotation	Abrupt Maneuver
(k)	2Oct00	A340	TC-JDN	N Atlantic	Cruise	Uncommanded Pitch
(l)	7Feb01	A320	EC-HKJ	LEBB	Landing	Abrupt Maneuver
(m)	17Mar01	A320	N-357NW	KDTW	Rotation	Pilot Induced Oscillation (PIO)
(n)	20Mar01	A320	D-AIPW	EDFF	Initial Climb	Uncommanded Bank
(o)	15Jun01	A320	N-561AW	KSAN	Maneuvering	Abrupt Maneuver
(p)	9Aug01	A320	G-EUPV	EGLL	Approach	FCS Mode Reversion
(q)	14Jun02	A330	C-GHLM	EDDF	Approach	Uncommanded Pitch
(r)	7Dec02	A320	C-GIUF	CYYZ	Approach	Pilot Induced Oscillation (PIO)
(s)	7Dec02	A320	C-GJVX	CYYZ	Approach	Pilot Induced Oscillation (PIO)
(t)	16Jun03	A320	C-GTDK	EGGD	Landing Flare	Abrupt Maneuver
(u)	15Apr04	A320	G-TTOA	LEMG	Descent	Abrupt Maneuver
(v)	25Jun05	A320	I-BIKE	EGLL	Approach	FCS Mode Reversion
(w)	1Aug05	B-777	9M-MRG	YPPH	Climb	Uncommanded Pitch
(x)	3May06	A320	EK-32009	URSS	Missed Approach	Collision with Terrain
(y)	23Oct06	A320	N-924FR	KDEN	Landing Flare	Uncommanded Pitch
(z)	27Mar07	E170	HZ-AEN	OERK	Descent	Uncommanded Pitch
(aa)	7Oct08	A330	VH-QPA	YPLM	Cruise	Uncommanded Pitch

Accident databases

During the course of reviewing these accidents and incidents, we noted that there is no consistent nomenclature of citing accidents and incidents. Accidents are variously cited by airline and flight number, by aircraft registration, or by the city in which they occur. In the U.S., generally, we use airline and flight number or the city. Even use of the city is clouded by using a suburb (such as Roselawn or Aliquippa) in place of the airport involved. Most foreign agencies use aircraft registration, although some hide the registration or airline. Manufacturers use the serial number, which can make tracing the incident difficult. It would be much easier if all used the aircraft registration.

Closing

It is clear that FBW systems are becoming increasingly complicated. These systems are difficult to design and test. The federal airworthiness requirements must be updated to include FBW system requirements. The current special conditions used for FBW system certification are incomplete. The flight crews have difficulty coping with a sudden change in the control system behavior due to unexplained/unannounced mode changes: "What's it doing now?" Training may need to be improved for situations in which immediate pilot intervention is required. Certification office personnel will need to be trained to identify potential FBW system design issues and to work with the applicants to ensure satisfactory resolution of potential design safety issues and to verify compliance. A special FBW incident and accident investigation board could be helpful in establishing future certification requirements and best design practices.

In spite of today's summary of FBW incidents, we must not forget that overall FBW and envelope protection have prevented accidents and saved lives. In the past 15 years, there have been 27 stall accidents in commercial transport operations with 848 fatalities—*not one was a FBW airplane.* ◆

USING ADS-B FOR
ACCIDENT INVESTIGATION AND PREVENTION

The author examines Automatic Dependent Surveillance Broadcast (ADS-B) workings and use at ERAU to show how its versatility of use can help bring a new level of safety in the air and on the ground.

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(This article is adapted with permission from the author's paper entitled Using ADS-B for Accident Investigation and Prevention, an Embry-Riddle Aeronautical University Perspective *presented at the ISASI 2009 seminar held in Orlando, Fla., Sept. 14–18, 2009, which carried the theme "Accident Prevention Beyond Investigation." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

Accident investigation and prevention go hand in hand. Current technologies allow investigators an unprecedented view and understanding of events leading to an accident. Automatic Dependent Surveillance Broadcast (ADS-B) uses conventional global navigation satellite system (GNSS) technology and a relatively simple broadcast communications link as its fundamental components. It is a very cost-effective method to provide traffic and weather information in remote areas of the world.

David Zwegers *is the director of aviation safety at* ERAU *Daytona Beach campus. He` has more than 3,500 accident-free hours of flight time with almost 3,000 hours of flight instructor time. He holds a BS in aeronautical science from ERAU and is completing his MS in aeronautics. He graduated from the NTSB Training Center, is a NAFI master CFI, and holds a commercial pilot certificate with SEL, MEL, instrument airplane, and CFI, CFII, and MEI. In October 2008, he was awarded the John K. Lauber Safety Award by the University Aviation Association.*

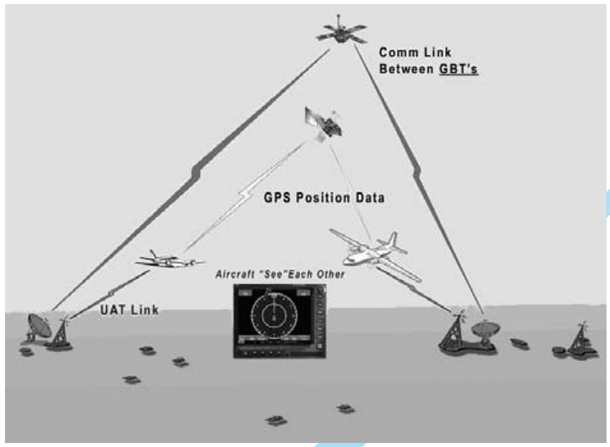


Figure A

Figure B

ADS-B is a new technology that allows pilots in the cockpit and air traffic controllers on the ground to "see" aircraft traffic (TIS-B) with much more precision than has been possible before.

A̲utomatic—It's always O̲N̲ and requires no operator intervention.

D̲ependent—It depends on an accurate GNSS signal for position data.

S̲urveillance—It provides "radar-like" surveillance services, much like radar.

B̲roadcast—It continuously broadcasts aircraft position and other data to any aircraft or ground station equipped to receive ADS-B.

Another important feature of ADS-B is that it provides crews with terrain and graphical and text weather information (FIS-B).

ADS-B-equipped aircraft broadcast their precise position in space via a digital datalink along with other data, including airspeed, altitude, and whether the aircraft is turning, climbing, or descending.

Unlike conventional radar, ADS-B works at low altitudes and on the ground so that it can also be used to monitor traffic on the taxiways and runways of an airport. It's also effective in remote areas or in mountainous terrain in which there is no radar coverage or where radar coverage is limited.

How does it work?

ADS-B relies on the satellite-based global positioning system to determine an aircraft's precise location in space (see Figure A). The system then converts the position into a digital code, which is combined with other information such as the type of aircraft, its speed, its flight number, and whether it's turning, climbing, or descending. The digital code containing all of this information is updated several times a second and broadcast from the aircraft on a discrete frequency called a datalink. This information is then displayed in the cockpit on a multifunction display (MFD) (see Figures B and C). It is more accurate and precise than traditional radar.

Other aircraft and ground stations within about 150 miles receive the datalink

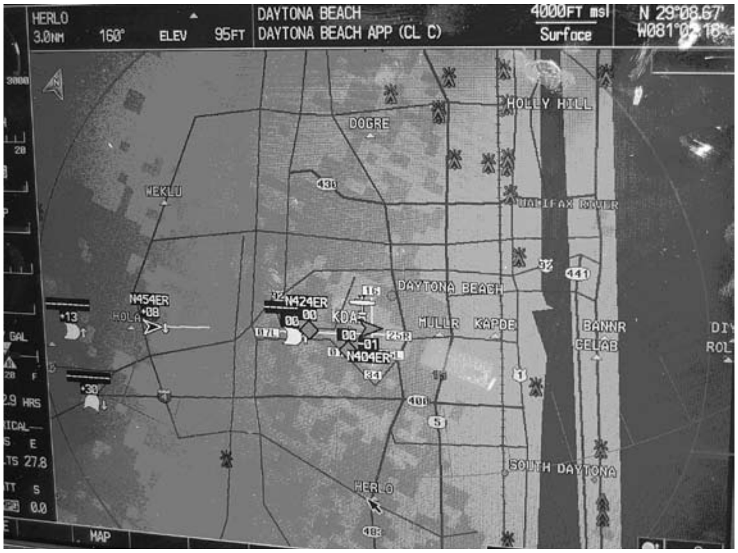


Figure C (above)
Figure D (upper right)
Figure 1 (right)

broadcasts and display the information in a user-friendly format on a computer screen. ERAU uses software developed by Johns Hopkins University called CRABS (Comprehensive Real-time Analysis of Broadcasting Systems) (see Figure D). ERAU is currently working on developing its own customized and enhanced version called SOFIA (Surveillance and Operations of Flight and Interactive Analysis), which will also provide live ATC audio and links to operations software (maintenance, scheduling, etc.) among other features.

Why ERAU?

During the past 20 years, the threat of a mid-air collision occurring on a commercial flight has been virtually non-existent, primarily due to the implementation of TCAS. General aviation accounts for almost all mid-air collisions, and many of them happen with student pilots on board. TCAS systems are impractical for small GA aircraft due to their size and prohibitive cost.

At a cost of about $20,000 per aircraft installed, ERAU has ADS-B on its entire fleet of 100 training aircraft at both the Daytona Beach, Fla., and Prescott, Ariz., campuses since 2003.

ADS-B has dramatically decreased the risk of mid-air collisions for ERAU in very congested airspace and has, without a doubt, saved lives by

- providing pilots real-time traffic information and a much greater margin in which to implement conflict detection and resolution, especially important below radar coverage (low altitudes and ground operations) avoiding mid-air collisions and runway incursions.
- providing pilots graphical and textual weather information.
- providing operators real-time information of aircraft location for planning purposes (spreading out aircraft to minimize congestion), and flight following (tracking) (see Figure 2).
- recording all data that can be used by the operator to increase safety and efficiency practices (accident/incident investigation, study pattern flows in/out of airspace, address noise complaints, etc). It has taken the guesswork out of the preexisting conditions.

ADS-B software also serves as a variant of a flight data recorder, without the need of any additional equipment installation. Additionally, the data are safely collected on the ground and always accessible, regardless of the location of the aircraft wreckage.

Examples of practical applications

Case #1. N462ER May 2007. Hard landing.

On the night of May 4, 2007, at approximately 2100 EDT, a student was conducting closed pattern operations at KDAB, using Runway 7R. At approximately 2137 EDT, while the pilot was attempting her first landing out of a scheduled 10, the aircraft bounced multiple times and the propeller struck the runway. The aircraft came to rest at the northeast corner of the intersection of Runway 16/34 and 7R.

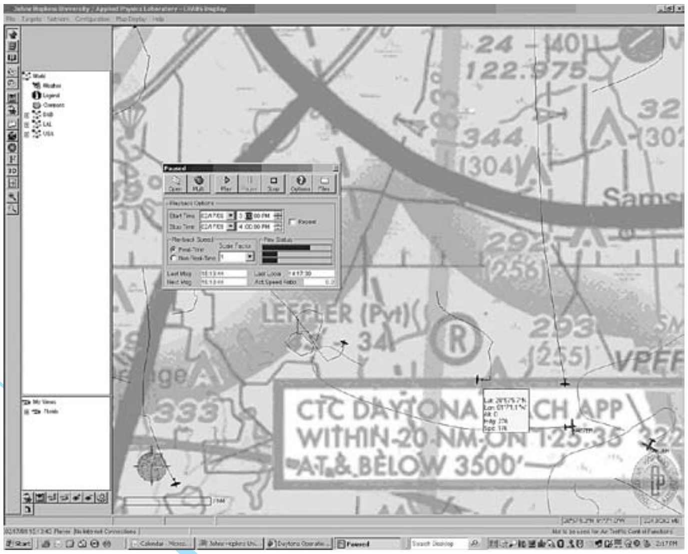
Visual meteorological conditions prevailed at the time and no flight plan was filed for the 14 CFR Part 91 instructional flights. There were no injuries reported to the private-rated pilot, but N462ER was substantially damaged.

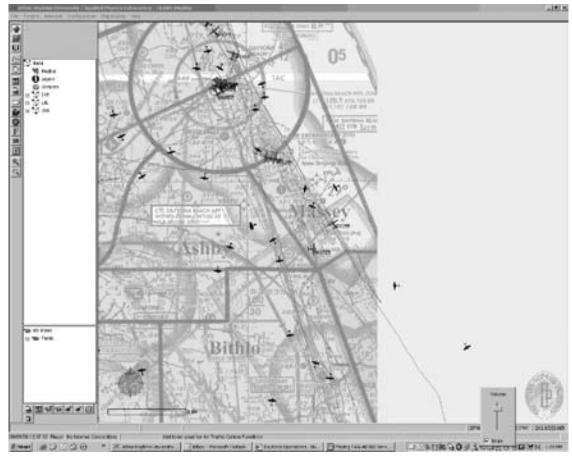
The NTSB probable cause: Pilot's improper flare at night. Contributing factor was a lack of recent night experience.

CRABS data were extensively used during the investigation and a key factor in determining errors at the organizational and supervisory levels. Several changes were implemented to eliminate future reoccurrence, like improved communications among instructors and staff, changes to training syllabi with emphasis on transition courses and visual illusions and airport/runway familiarity, changes to standard operating procedures with emphasis on stabilized approaches, etc. All 13 recommendations implemented by Flight Evaluation Board were adopted by the Flight Department.

Case #2. 712ER and 496ER August 2008. High wing vs. low wing.

During busy closed traffic operations in daylight VFR, a Cessna 172 is climbing on upwind and a Piper PA28-R is at pattern altitude turning downwind when a blocked transmission from ATC causes confusion and separation is compromised. ADS-B





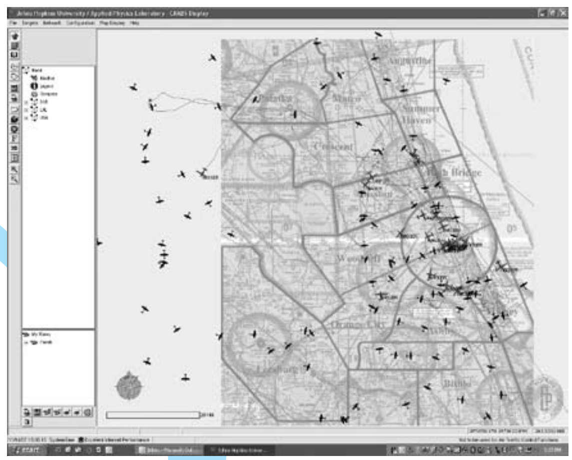


Figure 2 (above)
Figure 3 (right)
Figure 4 (upper right)

alerted the pilots on both aircraft of the conflict. This increased situational awareness was used for the initial avoidance maneuver as both aircraft did not have visual contact due the inherent restrictions in their design. CRABS data contributed to implementation of procedures at KDAB to reduce the risks of traffic pattern saturation. Specific transponder codes for non-ADS-B-equipped aircraft will allow transponders to remain in ALT mode, therefore making them "visible" to ADS-B.

Case #3. Recreation of flight path leading to fatal GA accidents.

Twin Commander May 2009. A Twin commander departs KDAB on VFR conditions and declares emergency shortly after takeoff. Aircraft crashes minutes later just short of the runway with one fatality and one injury. CRABS assisted investigators in determining probable cause (see Figure 1).

SR-20 February 2009. During a training flight that originated in KSFB, a Cirrus SR-20 impacts the ground fatally injuring both occupants. The aircraft is located the next day in a wooded area with the parachute deployed. CRABS aided investigators in reconstructing the profile of the flight (see Figure 2).

Case #4. Noise complaints and airspace violations.

ADS-B assists ERAU in enforcing noise abatement agreements and also protects pilots and operators against false identification or unjust noise complaints (see Figure 3).

Case #5. Flight following and overdue aircraft response.

The value of flight training is enhanced by the ability to debrief the conduct of a flight more accurately. Dual and solo flights can be monitored by fight operations for additional safety and improved communications (see Figure 4).

This level of situational awareness on the ground allows flight operators to prevent or reduce airport surface and airspace saturation, adapt dispatching limitations to current conditions, and many more efficiency measures.

Overdue aircraft response is mostly limited to positively identifying overdue aircraft on the computer followed by establishing communications with the crew. Many cases are just due to ATC delay vectors.

Future of ADS-B

With the advent of NexGen and other technologies, ADS-B will be an essential tool in aviation for decades to come. Software and hardware engineering will advance rapidly, making this system even more accessible and its use more common worldwide, signaling the end of radar. Embry-Riddle is actively participating with the FAA and ITT in the implementation of ADS-B service volumes nationwide. The aviation industry will soon benefit from a technology that allows safer and more efficient and reliable air traffic management on the ground and in the air. Pilots will have a level of situational awareness at their fingertips that is affordable and comprehensive, especially in general aviation.

Conclusion

ADS-B gives pilots, controllers, and operators a new level of situational awareness. Since its inception, it has given crews vital traffic and weather information previously unavailable even in the most remote areas. ADS-B hardware and software are evolving rapidly and becoming more available and viable for general aviation. ADS-B is accurate, reliable, comprehensive, and interactive. In combination with ATC audio recording, recording of ADS-B data can be a valuable investigative tool and give a much better picture of the events leading to an accident, taking much of the guesswork out and reducing hindsight bias. You now have an unprecedented look into the history of a flight to better help you understand the steps that lead to an event, not limited to large aircraft and operators anymore. ◆

ISASI 2010 Registration Opens

ISASI 2010, the Society's 41st annual international seminar on air accident investigation, is now open for registration according to Mamoru Sugimura, chairperson of Japan Local Seminar Committee (JLSC), which is hosting the event to be held in Sapporo, Japan, September 6-9. He welcomes delegates to the city of Sapporo saying that they will not only have a learning experience at the seminar, but also enjoy pleasant weather, delicious food, and Japanese culture during their stay.

The conference theme, "Investigating ASIA in Mind—**A**ccurate, **S**peedy, **I**ndependent, and **A**uthentic," will be reflected in the 25 to 30 technical papers to be presented. The day-long tutorial program will feature "Investigating Human Factors, Human/Machine Interface," and "Aircraft Numbers Are Increasing Worldwide—How Do We Prevent Accidents?"

The seminar program registration fee (in U.S. dollars) by August 20 is member, $595; non-member, $645; student member, $200. If registration is made after August 20, the fees are $620, $670, and $225, respectively. Day pass fee for any of the 3 days is $200. The companion fee is $350 by August 20 and $375 thereafter. The member fee for the one-day tutorial is $165; student member, $100. Fee for a single event: welcome reception $50, Tuesday night dinner $100, and awards banquet $100.

The seminar's website, through which conference and hotel registration will be made, is accessible through the ISASI website, www.isasi.org. All areas of delegate interest are easily identified and accessed on the site. The hotel reservation page is being maintained by the Japan Travel Bureau (JTB), one of the leading travel agencies in Japan. The reservation page lists three hotels: Royton Sapporo, Sapporo ANA Hotel, and Prince Hotel. Fees (payable in Japanese yen) include breakfast, service charge, and 5% tax. The Royton's fee is 11.500 yen (single person in a twin-bed room) and 16.000 yen (two persons in a twin-bed room). ANA's fee is 10,500 yen (single person in a twin-bed room) and 16.800 yen (two persons in a twin-bed room). Prince's fee is 13.500 yen (single person in a twin-bed room) and 18.900 yen (two persons in a twin-bed room). At press time, the exchange rate was US$1 to the Japanese yen 93.588.

Social aspects of the conference will see the companion program doing sightseeing near Sapporo, making a visit to the Central Wholesale Market, and attending a cultural program including Kimono dressing, a tea ceremony, and a flower arrangement. The Tuesday evening dinner will involve a delicious dinner at Sapporo Bier Garten with fresh beer brewed by Sapporo Beer Company, one of Japan's leading beer companies. And the Friday optional tour will take attendees to Noboribetsu hot spring, which offers a relaxing change of pace and provides a refreshed feeling in both mind and body. ◆

ANZSASI 2009 Opens June 4 at Canberra, Australia

The Australian and New Zealand Societies of Air Safety Investigators joint 2010 regional air safety seminar opens June 4 at the Rydges Lakeside Hotel, Canberra, Australia. The regional air safety seminar is hosted alternately by the two societies.

The seminar will include reports on contemporary transport safety including recent investigations (road, rail, marine, aviation) and on the issues facing safety investigators in the future.

Registration instructions for both the seminar and hotel accommodations are available at the Australian SASI website, www.asasi.org. Seminar registration costs are (in Australian dollars): member: $345, after April 1, $395; non-member: $395, after April 1 $445. Methods of payment are explained on ASASI's website. Hotel registration is open.

For more information contact Paul Mayes at e-mail cpmayes@aapt.net.au or Lindsay Naylor at e-mail lnaylor@spitfire.com.au. ◆

Etihad Airways Hosts Reachout No. 35

Etihad Airways hosted the 35th ISASI Reachout workshop on incident investigation and human factors in Abu Dhabi, United Arab Emirates (UAE), in November 2009. Capts. Paolo La Cava, manager of flight safety, and Adrian Aliyuddin, manager of safety assurance, opened the workshop.

Approximately 20 participants from Etihad Airways covered all operational areas, including pilots (involved in company safety management), maintenance and quality engineers, aviation security personnel, and cabin crew. An invitation to the workshop had also been extended to other operators in Abu Dhabi; there were two participants from Abu Dhabi Aviation. ISASI certificates were presented to all the participants.

Caj Frostell, ISASI international councillor, and Mike Doiron served as the ISASI instructors. Presentations were provided on

- international requirements for SMS and airline safety programs,

Participants at the 35th ISASI Reachout workshop in Abu Dhabi, United Arab Emirates.

2009 Annual Seminar Proceedings Now Available

Active members in good standing and corporate members may acquire, on a no-fee basis, a copy of the *Proceedings of the 40th International Seminar*, held in Orlando, Fla., USA, Sept. 14–18, 2009, by downloading the information from the appropriate section of the ISASI web page at http://www.isasi.org. The seminar papers can be found in the "Members" section. Alternatively, active members may purchase the *Proceedings* on a CD-ROM for the nominal fee of $15, which covers postage and handling. Non-ISASI members may acquire the CD-ROM for US$75. A limited number of paper copies of *Proceedings 2009* are available at a cost of US$150. Checks should accompany the request and be made payable to ISASI. Mail to ISASI, 107 E. Holly Ave., Suite 11, Sterling, VA USA 20164-5405. ◆

Preface: Accident Prevention Beyond Investigation
By Frank Del Gandio, President, ISASI
Keynote Address: What Is Next?
By Deborah Hersman, Chairman, U.S. National Transportation Safety Board, Washington, D.C., USA
Lederer Award: Two Receive 2009 Jerome F. Lederer Award
By Esperison Martinez, Editor, ISASI Forum

TUESDAY, SEPTEMBER 15
Closing the Gap Between Accident Investigation and Training
By Michael Poole, Executive Director and Chief Investigator, and Lou Németh, Chief Safety Officer, CAE Flightscape
How Significant Is the Inflight Loss of Control Threat?
By Capt. John M. Cox, FRAeS, and Capt. Jack H. Casey, FRAeS, Safety Operating Systems, L.L.C., Washington, D.C.
Reducing the Risk of Runway Excursions
By Jim Burin, Director of Technical Programs, Flight Safety Foundation
Developing Investigations to Enhance Safety Worldwide
By Marcus Costa, Chief, Accident Investigation and Prevention Section, ICAO
A Comparison Study of GPS Data and CDR Radar Data Using a Fully Instrumented Flight Test
By Ryan M. Graue, Aeronautical Engineer, AvSafe, LLC; Jean H. Slane, Senior Consultant, Engineering Systems Inc.; Dr. Robert C. Winn, Principal Engineer, Engineering Systems Inc.; W. Jeffrey Edwards, President, AvSafe, LLC; and Krista B. Kumley, Consultant, Engineering Systems Inc.
Safety Strides Foreseen with Lightweight Flight Recorders for GA
By Philippe Plantin de Hugues, Ph D., Bureau d'Enquêtes and d'Analyses pour the sécurité of l'aviation civile, Head of Flight Recorders and Avionic Systems Division
Using ADS-B for Accident Investigation and Prevention, an Embry-Riddle Aeronautical University Perspective
By David Zwegers, Director of Aviation Safety, Embry-Riddle Aeronautical University, Daytona Beach, Fla., USA

WEDNESDAY, SEPTEMBER 16
Human Error Prevention: Using the Human Error Template to Analyze Errors in a Large Transport Aircraft for Human Factors Considerations
By Wen-Chin Li, Head of Graduate School of Psychology, National Defense University, Taiwan; Don Harris, Director of Flight Deck Design and Aviation Safety Group in Human Factors Department, Cranfield University, United Kingdom; Neville A. Stanton, Chair in the Human Factors of Transport, School of Civil Engineering and the Environment, University of Southampton, United Kingdom; Yueh-Ling Hsu, Professor in the Department of Air Transportation, Kainan University, Taiwan; Danny Chang, Head of Training Division, China Airlines, Taiwan; Thomas Wang, Director of Flight Safety Division, Aviation Safety Council, Taiwan; Hong-Tsu Young, Managing Director of the Executive Yuan, Aviation Safety Council, Taiwan
An Analysis of Human Factor Aspects in Post-Maintenance Flight Test
By Capt. Claudio Daniel Caceres, Senior Safety Advisor, Continuous Safety®, Switzerland
Findings of Using Human Factors Analysis and Classification System (HFACS) as a Tool for Human Factors Investigation
By Yung-An Cheng, Engineer Flight Safety Division, Aviation Safety Council (ASC), Taiwan; Thomas Wang, Director of Flight Safety Division, ASC, Taiwan; Jenn-Yuan Liu, Engineer Flight Safety Division, ASC, Taiwan; Chi-Liang Yang, Associate Engineer, Flight Safety Division, ASC, Taiwan; Dr. Wen-Chin Li, Head of Graduate School of Psychology, National Defense University, Republic of China
Closing the Loop on the System Safety Process: The Human Factors Intervention Matrix (HFIX)
By Dr. Scott Shappell, Professor, Clemson University, Clemson, S.C., and Dr. Douglas Wiegmann, Associate Professor, University of Wisconsin, Madison, Wisc.
At What Cost? A Comprehensive and Statistical Analysis of EMS Helicopter Accidents in the United States from 1985 to 2007
By Christine Negroni (FO5208) and Dr. Patrick Veillette
Sifting Lessons from the Ashes: Avoiding Lost Learning Opportunities
By Ludwig Benner, Jr., Principal, Starline Software Ltd., Oakton, Va., USA, and Ira J. Rimson, Forensic Engineer, Albuquerque, N.M., USA
Using the Best Cost Analysis for Effective Safety Recommendations
By Dr. Simon Mitchell, Aviation Director, RTI Ltd, London, UK, and Visiting Fellow, Cranfield University, UK, and Professor Graham Braithwaite, Director, Cranfield University Safety and Accidents Investigation Centre, UK
Safety: A Function of Leadership
By Gary D. Braman, System Safety Engineer, Sikorsky Aircraft Corporation, Huntsville, Ala., USA

THURSDAY, SEPTEMBER 17
A Review of Fly-by-Wire Accidents
By Dr. R.L. (Dick) Newman, Seattle, Wash., and A.A. (Tony) Lambregts, Chief Scientist-Advanced Controls, FAA, Renton, Wash., USA
Simulation of Emergency Evacuation Factors in Transport-Category Aircraft
By Dr. Eric Robert Savage, Assistant Professor, ERAU, Prescott, Ariz., and Erich Skoor, Graduate Student, ERAU, Prescott, Ariz., USA
The Accident "CAUSE" Statement—Is It Beyond Its Time?
By Robert MacIntosh (MO0996), Chief Advisor, International Safety Affairs, U.S. National Transportation Safety Board, Washington, D.C., USA
Accident Prevention: Pushing the Limits
By Bernard Bourdon, Accident Investigation Manager, European Aviation Safety Agency, EU
Seminar Summary of ISASI 2009: Accident Prevention Beyond Investigation
By John Guselli, JCG Aviation Services and Chairman of ISASI's Reachout Committee

GUEST SPEAKERS
Communication Challenges After the Air France Flight 447 Accident
By Marine Del Bono, Head of Public Affairs Division, Bureau d'Enquêtes et d'Analyses (BEA), France
The United Kingdom Experience
By David Miller, UK Deputy Chief Inspector of Air Accidents, Air Accidents Division Branch
Initial Investigation of Serous Accidents: The JTSB's Experience
Ikuo Takagi, Investigator General for Aircraft Accident, the Japan Transportation Safety Board
The *Continuous* Challenge for U.S. Air Safety Investigators Assisting in International Investigations
By Dujuan B. Sevillian, 2009 Rudolf Kapustin Memorial Scholarship Winner
Caring for the Mental Health of Air Safety Investigators
By Brian Dyer, 2009 Rudolf Kapustin Memorial Scholarship Winner
Challenges to ASI Investigations
By Murtaza Teyla, 2009 Rudolf Kapustin Memorial Scholarship Winner

(Editor's note: Text unavailable for presentations by Paul Arsianian, Robert Sumwalt, and Mark Clitsome.)

- introduction to SMS and lessons learned,
- developing the right safety culture,
- human performance,
- stress and fatigue,
- SHELL model,
- non-punitive safety programs,
- incident reporting within an airline,
- in-house incident investigations,
- SMS hazard identification and risk management,
- safety analysis,
- automation: friend or foe,
- threat and error management,
- naturalistic decision-making (accident prevention),
- incident investigation case studies,

In Memoriam

Roscoe M. Holderman (LM2479), Lillian, Ala., USA, May 29, 2009
Felix H. Medak (LM0628), North Hollywood, Calif., USA, July 15, 2009
Edwin L. Shaw (LM2801), Ventura, Calif., USA, unknown month, 2008 ◆

- human factors analysis classification system,
- weather-related risks, and
- SMS action plan.

The ISASI instructors prepared their training material comprising paper handouts and a CD with published manuals and booklets. Each participant received copies of the documents and a CD with considerable background materials for future reference. ISASI membership forms and corporate membership forms were made available to the participants.

The arrangements at Etihad Airways and in Abu Dhabi were accomplished by Capt. Aliyuddin. The outstanding assistance rendered to the instructors was invaluable in all aspects. Instructor travel and accommodations, in Abu Dhabi was provided by Etihad Airways. Etihad Airways management and the participants expressed high appreciation to ISASI for again bringing the Reachout workshop program to Abu Dhabi. ◆

CAAS joins ASPIRE

The Civil Aviation Authority of Singapore (CAAS) has joined the Asia and Pacific Initiative to Reduce Emissions (ASPIRE) partnership by signing the joint agreement on February 1. ASPIRE was initiated by the U.S. Federal Aviation Administration (FAA), Airways New Zealand, and Airservices Australia. The Japan Civil Aviation Bureau joined ASPIRE when it signed the joint agreement in October 2009 in Osaka, Japan.

ASPIRE is a partnership of air navigation service providers focused on environmental stewardship in the region. The ASPIRE partnership is a comprehensive approach to environmental stewardship in a region in which significant disparities exist in the level of available service provision. Under ASPIRE, current and future partners pledge to adopt and promote best practices that have demonstrated and proven successful in reducing greenhouse gases and developing work programs to promote future gains with respect to the environment.

Other signatories of the ASPIRE joint agreement are the U.S. Federal Aviation Administration (February 2008), Airways New Zealand (February 2008), Airservices Australia (February 2008), and the Japan Civil Aviation Bureau (October 2009). ◆

President Nominates Weener for NTSB

President Obama has nominated Earl F. Weener for a seat on the National Transportation Safety Board. Weener is a fellow at the Flight Safety Foundation in Alexandria, Va. While a member of the Foundation, he worked on runway safety, ground accident prevention, and approach and landing accident reduction. Before his retirement from Boeing in 1999, Weener's positions included chief engineer for airworthiness, reliability, maintainability and safety; chief engineer of systems engineering; and chief engineer for safety technology development.

Weener is also a licensed commercial

NEW MEMBERS

Corporate
Nova Aerospace, Australia
Brett Martin, Systems Engineer
Seamus Miller, Systems Engineer
Flight Data Services Ltd., United Kingdom
Capt. Simon Searle, Safety Projects Manager
Dave Jesse, CEO

Individual
Akhand, Imam, HMA, Whitby, Canada, ON
Anthony, Kristine, E., Prescott, USA, AZ
Balac-Moreira, Tiago, G.C., Singapore, Singapore
Barry, David, J., Walton on Thames, Surrey, United Kingdom
Bennett, Derrick, D., Wichita, USA, KS
Bevis, Philip, A., Basingstoke, Hampshire, United Kingdom
Blacklock, Thomas, L., Crossfield, Canada, AB
Blankenstein, Eric, Brisbane, Australia, QLD
Brown, David, H., Cook, Australia, ACT
Cant, Andrew, Auckland, New Zealand
Carty, Belinda, R., Emerald, Australia, QLD
Chen, Kuan-Yu (Kevin), Port Orange, USA, FL
Chiu, Kevin, I, Taipei, Taiwan
Demko, Jill, M., Seymour, USA, CT
Dimoutsikos, Evan, D., Chicago, USA, IL
Duprie, Terry, L., Lake Charles, USA, LA
Eiser, Abraham, D., Marietta, USA, GA
Findlay, Leanne, K., Richmond, Australia, VIC
Gannot, Yair, H., Alfei Menashe, Israel
Garstang, John, H., Ladysmith, Canada, BC
Greenwood, Robert, E., Calgary, Canada, AB
Harvey, Beverley, Ottawa, Canada, ON
Hetherington, Kathryn, J., Edina, USA, MN
Huddle, Jr., David, W., Melbourne, USA, FL
Khoo, Steven, Singapore, Singapore
King, Robert, D., Daytona Beach, USA, FL
Lopes, Nicolas, Covina, USA, CA
Lozano, Juan, C., Madrid, Spain
Madden, Gregory, M., Chapman, Australia, ACT
Mascheroni, Roberto, Bensalem, USA, PA
Matsch, Katherine, M., Lakewood, USA, WA
Miller, Andrew, B., Bieldside, United Kingdom
Mohr, Brittany, D., Orange Park, USA, FL
Musselman, Brian, T., North Beach, USA, MD
Nail, Martyn, P., Palmerston North, New Zealand
Parker, Simon, M., Cable Beach, Australia, WA
Patrick, Trudy, Port of Spain, Trinidad, Tobago
Pontes, Mauricio, F., Sao Paulo, Brazil, S.P.
Popek, Matthew, M., Savage, USA, MN
Ruiz Zaera, Isabel, Prescott, USA, AZ
Shade, Tomas, Melbourne, USA, FL
Stas, Olivia, Anchorage, USA, AK
Sunny, De Paul, Daytona Beach, FL
Svavarsson, Jon, Kopovog, Iceland
Taufa, Samiu, Port Moresby, Papua New Guinea, N.C.D.
Tocwish, Timothy, C., Joliet, USA, IL
Turyamubona, Ronald, Entebbe, Uganda
Voss, David, J., Brisbane, Australia, QLD
Ward, Kevin, Waitakere, Auckland, New Zealand
Westgate, Benjamin, A., Forestdale, USA, MA
Whiteis, Barnabas, G., DPO, USA, AA
Wicksteed, Jason, Cairns, Australia, QLD
Wong, Wai-Yee (Maggie), Daytona Beach, USA, FL
Yellman, Ted, W., Bellevue, USA, WA
York, John, P., Tyndall AFB, USA, FL
Yurdakul, Hakan, Antalya, Turkey,
Zabawa, Douglas, J., Bristol, USA, CT ◆

pilot and flight and ground instructor. He received a doctorate in aerospace engineering from the University of Michigan. ◆

Global Aviation Regulators Agree to Share Safety Data

A broad alliance of aviation regulators and industry groups recently signed an agreement to collect and jointly analyze airline safety data from around the world, a move that has the potential to produce major advances in responding to safety threats, reported Flight Safety Information, an online aviation reporting site.

Under the "declaration of intent" signed at an aviation conference in Montreal, the Federal Aviation Administration, the European Commission, and the United Nations International Civil Aviation Organization will link up with the airline industry's International Air Transport Association to establish a common information-sharing network.

One aim of the agreement is to help regulators and carriers in developed countries confront subtle hazards that otherwise might go undetected. Another benefit is expected to be enhanced safety programs in parts of Africa, Latin America, and other regions in which cutting-edge data analysis often isn't available and accident rates historically have been much higher than in North America or Europe.

Proponents agree that many difficult hurdles remain and that a full-scale implementation is likely years away. One challenge is creating sophisticated new computer tools able to sort through a barrage of data. The agreement also calls for follow-on efforts to resolve technical, legal, and confidentiality issues, as well as to develop new ways to disseminate lessons learned after analyzing the data.

Still, the latest development is widely seen as an important building block to reach the next phase of commercial aviation safety: identifying and eliminating incipient hazards before they can cause dangerous incidents or crashes. Sifting through global data, for example, could provide early warnings about a pattern of dangerously fast or steep approaches to certain airports. It also might help regulators better understand the causes of some engine or flight computer malfunctions before the problems become more frequent and pose a greater hazard to passengers.

Each of the participating organization already has its own information-gathering and analysis system, but the databases aren't complementary and detailed results often aren't shared across continents.

Initially, the focus will be on sharing audits of airlines and the effectiveness of oversight by air safety regulators in individual countries. The FAA and the European Commission, for instance, conduct separate assessments of foreign carrier safety, but now there is no formal way to compare data. Similarly, the FAA has faced obstacles recruiting European and other foreign carriers to contribute their closely guarded data to the agency's most comprehensive safety analysis project.

If the initiative succeeds, proponents ultimately see broader applications. They envision a worldwide repository of voluntary reports of pilot mistakes, other operational problems, maintenance slip ups and lapses by air traffic controllers. Better data sharing could also help airlines avoid issues such as collisions on the tarmac between planes and airport service vehicles, a problem that costs airlines about $4 billion annually. ◆

NTSB Releases Federal 'Most Wanted List'

The U.S. National Transportation Safety Board (NTSB) recently issued its 2010 Most Wanted List of Transportation Safety Improvements, adding rail, aviation, and marine issues and updating the status of other issues on the list.

"Every one of the hundreds of currently open safety recommendations address concerns that the Safety Board has uncovered in its accident investigations," NTSB Chairman Deborah A.P. Hersman said. "But the recommendations on the Most Wanted List represent those improvements that can have the widest benefit."

Besides removing two issue areas on the list, the Board reviewed the remaining 13 issue areas on the list and added two new ones. Each issue area is color coded by the NTSB to designate its action/timeliness: red for unacceptable response; yellow for acceptable response, progressing slowly; and green for acceptable response, progressing in a timely manner.

The 2010 Most Wanted List as it pertains to aviation follows:

"Improve Oversight of Pilot Proficiency"—This new issue area added by the Board contains two 2005 recommendations calling on the FAA to require airlines to obtain histories of flight check failures by pilot applicants and to require special training programs for pilots who have demonstrated performance deficiencies. The designation is red.

"Require Image Recorders"—Although cockpit voice recorders and flight data recorders record sounds and relatively comprehensive airplane data during an emergency, they do not show the critical cockpit environment leading up to the emergency. The Board has requested image recorders for large transport-category aircraft and for smaller aircraft that do not otherwise have recording devices. This issue was designated red.

"Improve the Safety of Emergency Medical Services Flights"—The Board has issued a series of recommendations aimed at improving the safety of this vital service to the public. The FAA has announced it will issue a proposed rule that will address some of these concerns, and the Board has upgraded the designation for this issue from red to yellow.

"Improve Runway Safety"—The deadliest accident in aviation history was a runway collision in 1977. Runway accidents and incidents continue to occur, including a fatal regional jet accident in Kentucky in 2006 and an incident last year in which an airliner landed on a taxiway in Atlanta. The NTSB has a series of recommendations aimed at preventing such occurrences, including requiring moving map displays in the cockpit, giving immediate warnings to the cockpit of impending incursions, and requiring landing distance assessments with an adequate safety margin for every landing. The designation remains red.

"Reduce Dangers to Aircraft Flying in Icing Conditions"—An airliner crash in 1994 prompted the NTSB to examine the issue of airframe structural icing and conclude that certification standards have been inadequate. The NTSB continues to believe that the FAA has failed to make adequate progress in this area and has kept the designation at red.

"Crew Resource Management for Part 135 Carriers"—Federal regulations require Part 121 and Scheduled Part 135 operators to provide pilots with crew resource management training. The NTSB has investigated a number of Part 135 on-demand operations in which such training was not provided and errors by the crew led to accidents. The FAA has proposed to require a form of CRM training for these carriers, and the Board has upgraded the designation from red to yellow. ◆

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Accident Investigation & Prevention Bureau
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Aviation Safety Council
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Finnish Military Aviation Authority
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Flight Data Services Ltd., United Kingdom
Flight Safety Foundation
Flight Safety Foundation—Taiwan
Galaxy Scientific Corporation
General Aviation Manufacturers Association
GE Transportation/Aircraft Engines
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Gulf Flight Safety Committee, Azaiba, Oman
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Hong Kong Airline Pilots Association
Hong Kong Civil Aviation Department
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Independent Pilots Association
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Interstate Aviation Committee
Irish Air Corps
Irish Aviation Authority
Japan Airlines Domestic Co., LTD
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WHO'S WHO

Parker Aerospace

(Who's Who is a brief profile prepared by the represented ISASI corporate member organization to provide a more thorough understanding of the organization's role and functions.—Editor)

Parker Aerospace is an operating segment of Parker Hannifin Corporation and designs, manufactures, and services hydraulic, fuel, flight control, and pneumatic components and systems and related electronic controls for aerospace and other high-technology markets.

Based in Irvine, Calif., Parker Aerospace operates eight divisions consisting of 23 facilities in the Americas, Europe, and Asia. Divisions include aircraft wheel and brake in Avon, Ohio; electronic systems in Long Island, N.Y.; gas turbine fuel systems in Mentor, Ohio; hydraulic systems in Kalamazoo, Mich.; stratoflex products in Ft. Worth, Tex.; and fluid systems, control systems, and customer support operations in Irvine, Calif.

Parker products are used on virtually every aircraft manufactured throughout the world today, including commercial transports, military fixed-wing planes, regional and business aircraft, helicopters, missiles, and unmanned aerial vehicles.

Parker's history in aerospace extends forward from Lindbergh's Atlantic flight to every manned lunar landing and on to today's international space station missions. During that time, it has contributed to making flight and space travel more reliable, faster, more secure, and above all safer. In addition to flight surface controls, Parker manufactures systems for hydraulic power, fuel supply and balancing, engine fuel combustion, cabin and cargo area surveillance, heating and cooling controls, and systems intended for safety such as fuel tank inerting.

Several decades ago, Parker pioneered the use of fuel inerting on military aircraft by inserting inert gas in the ullage of a fuel tank to suppress combustion. Using this knowledge and experience, Parker played a key role in applying this technology to commercial aircraft tanks and developing the onboard inert gas generating systems (OBIGGS) to prevent disastrous ignition of a fuel tank.

An air safety department at Parker Aerospace was created in 2006 and consists of an air safety officer and a "go team" consisting of design, reliability, and aftermarket engineers knowledgeable in the design, manufacture, and use of all Parker product lines. All go-team members are trained and ready to assist investigations of Parker Aerospace products both on site and during examinations at Parker facilities.

All Parker facilities have secured storage for components for testing and examination, ensuring that packages are received unopened and that all components remain intact and unaltered for an examination. Parker Aerospace has participated in accident and incident investigations, and information and lessons learned in these investigations have been incorporated to improve the safety of component and system operation.

ISASI membership has proven to be very beneficial to Parker Aerospace for networking with industry peers and operators alike to learn best practices in occurrence investigation and the latest best practices of proactive safety management. ◆