Air Safety Through Investigation

Proceedings of the 40th Annual International Seminar

'Accident Prevention Beyond Investigation'

Sept. 14–17, 2009
Orlando Fla., USA

ISASI Proceedings

VOLUME 13

Publisher
ISASI (Frank Del Gandio, President)

Editorial Advisor
Richard B. Stone

Editorial Staff
Susan Fager
Esperison Martinez

Design
William A. Ford

ISASI Proceedings (ISSN 1562-8914) is published annually by the International Society of Air Safety Investigators. Opinions expressed by authors are not necessarily endorsed or represent official ISASI position or policy.

Editorial Offices: 107 E. Holly Ave., Suite 11, Sterling, VA 20164-5405 USA. Telephone: (703) 430-9668. Fax: (703) 450-1745. E-mail address: isasi@erols.com. Internet website: http://www.isasi.org.

Notice: The *Proceedings* of the ISASI 40th annual international seminar held in Orlando, Fla., features presentations on safety issues of interest to the aviation community. The papers are presented herein in the original editorial content supplied by the authors.

Publisher's Editorial Profile: *ISASI Proceedings* is printed in the United States and published for professional air safety investigators who are members of the International Society of Air Safety Investigators. Content emphasizes accident investigation findings, investigative techniques and experiences, and industry accident-prevention developments in concert with the seminar theme "Accident Prevention Beyond Investigation."

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ISSN 1562-8914

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PREFACE
Accident Prevention Beyond Investigation

By Frank Del Gandio, President

Welcome to Orlando, hometown of our famous Mickey and his friends—land of adventure, magic, imagination, fun, and excitement. We are all characters of our own, and we are in this hall today in Orlando to participate in the 40th annual seminar of the International Society of Air Safety Investigators. When ISASI started, the adjective "international" was a bit presumptuous as ISASI was, in fact, only Jerry Lederer and a few close friends. Today ISASI is the premier professional society for accident investigators and for others whose work revolves around accidents and accident prevention.

ISASI now is truly international, with chapters and members from all over the world. Next year, for example, the annual seminar will meet for the second time in Asia, and we recently held the seminars in Australia and Halifax. We have aviation safety professionals here this week from all over the world. ISASI brings a rich mixture of prospectives from different continents, different cultures, and different national systems and aviation markets.

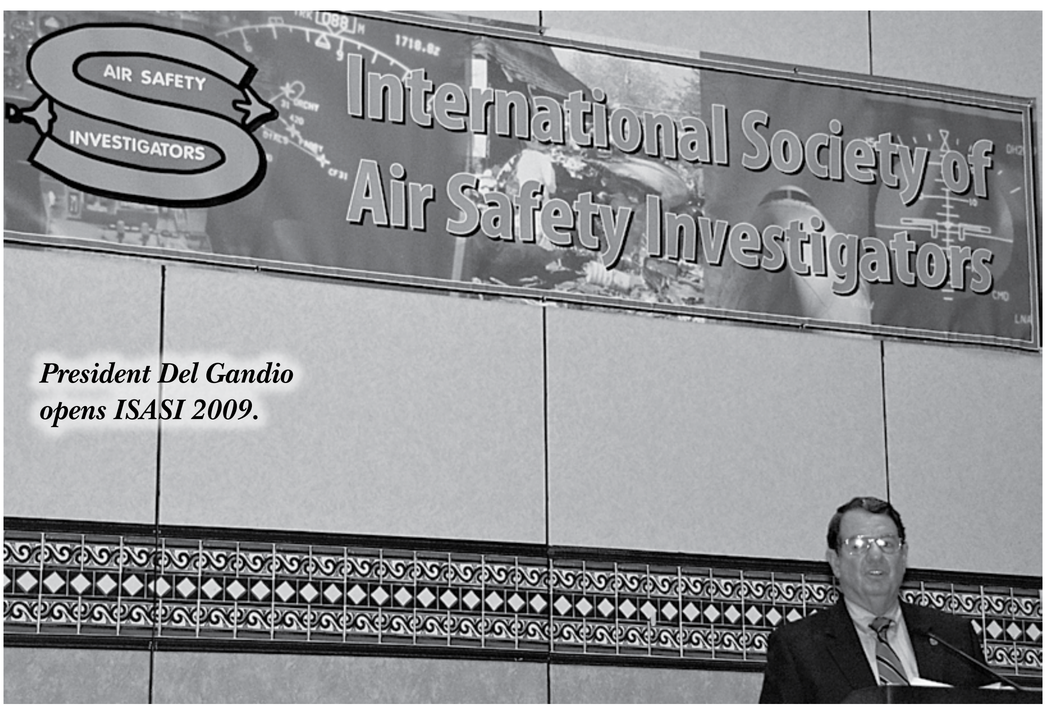
Every year I point out that the room is full of expertise, and this year is no different. Any students or entry-level professionals should take advantage of the expertise that is all around you. Professionals with extensive experience should also make certain they do not overlook the chance to learn something. If you have a question about the details of a particular accident, or the subtleties of a particular aircraft system, or broader questions about the overall state of aviation safety, or some other topic, someone in this room can provide encyclopedic answers to your questions. In short, take advantage of the expertise that is here this week and share your own knowledge.

Our theme this year is "Accident Prevention Beyond Investigation." It is a timely theme because the entire field of aviation safety is changing rapidly and in multiple ways. Start with the bottom line: fatal accidents. Both the rate for fatal accidents and the absolute number of fatal accidents are much lower today for airlines in most regions of the world than they were just a decade ago. I realize that major accidents have not gone away, and any talk about a nearly permanent zero accident rate is premature rhetoric, but we continue to move in that direction.

The world's airline industry has more than doubled in the past two decades, but fatal accidents have gone down by more than half with the important exception of sub-Saharan Africa. Safety officials in any other industry in the world economy would be thrilled to have numbers like that.

Most regions of the world also are seeing rapid improvements in general aviation. The U.S. experience in recent years is fairly representative. Just 15 years ago, we were still having close to 500 fatal accidents a year in general aviation and air taxi operations. This year we expect to end up at around 260; again, down by nearly half, and one third of the remaining fatal accidents now involve amateur-built and other experimental aircraft. In short, among the fleet in which governments have a significant stake, the improvement in recent years has been dramatic.

Lots of factors explain these improvements, but technology is the primary explanation. Technology also is changing accident investigation. For starters, by greatly reducing the frequency of accidents, technology has reduced the demand for our services. It is that simple. In addition, it has changed the way that we do our work. More and more of the work is conducted off scene in laboratories, based on systems that continue to capture more and more data.



President Del Gandio opens ISASI 2009.

E. MARTINEZ

On-scene work will always be important, and we will continue to examine wreckage paths, impact foot prints, engine damage, and so on. But even in general aviation, more of our analysis is moving off scene, and that trend will continue for the foreseeable future. Technology has driven an even greater change in the broader field of accident prevention.

For several years now, we have had the benefit of systematic analysis of flight operations data, or "FOQA." We now are at a point where we can monitor well-documented precursors to several categories of accidents and take action before an accident occurs. For example, in the United States, we have begun to identify specific arrivals and approaches into specific airports where GPWS alerts and TCA resolution alerts are abnormally high. Similarly, we have identified areas in which unstable approaches are more common and in which long landings are more common, and so on. More to the point, we have been able to use these data to change local air traffic procedures, to change training and procedures within particular airlines, and to change emphasis areas within our safety inspection programs. All these efforts have reduced the risk of CFIT accidents, mid-air collisions, undershoots, runway excursions, etc.

These monitoring efforts are based largely on exhaustive analytical efforts that have examined hundreds of well-documented accidents from around the world in order to identify those parameters that we should and can measure, and these methodologies are changing accident prevention in a fundamental way. Few of the people who have conducted the analyses or who have undertaken the necessary analyses are accident investigators, but they understand accidents, concepts of risk, and overall safety performance.

This is the broader community and the intellectual framework in which accident investigation must work if we are to continue to make our contribution. Yet, at the same time, that broader community understands that it cannot avert every accident. My own country has had a rash of major accidents in the past 18 months or so. Most of those accidents have involved the usual suspects, like failure to monitor flight instruments, poor basic flying skills, maintenance issues, unstable approaches, management practices, and so on. Nevertheless, these data efforts have documented in detail the nature of those events and have reduced the risk and frequency of those events

Yet, analysis of selected parameters, even hundreds of parameters, will never anticipate accidents like the B-777 at Heathrow, or even the wrong runway takeoff at Lexington, because that work relies fundamentally on knowing what questions to ask of the data. That is where accident investigation will continue to play a fundamental role in the system, by documenting and providing basic knowledge about the frequency with which well-understood failures continue to produce serious outcomes and by understanding and documenting new outcomes, such as the simultaneous failure of two jet engines at Heathrow.

The bottom line for accident investigation is both complicated and simple. It is complicated because we must recognize the changes that are taking place in the broader field of accident prevention. It is complicated because we need to become much more active with that broader safety community, and it is complicated because, to be honest, we have to show more intellectual respect for what that broader community brings to aviation safety and to accident prevention. In short, it is complicated because we need to recognize more directly a basic idea that we have always understood at some level: accident investigation is but one element, albeit a key element, in the ultimate mission of preventing and reducing accidents.

Yet, the bottom line for accident investigation also is quite simple. It is simple because accident investigation will remain the primary source for understanding accident scenarios about which we had known little or nothing, such as at Heathrow. It also will remain the primary source for documenting the frequency at which well-known risks continue to rear their ugly heads and lead to serious outcomes. In short, your work and the well-documented reports that you produce will continue to be the source material from which analysts begin to understand what questions they need to ask of the data.

In the end, our profession is changing as we speak. We will find ourselves working more and more actively with a broader safety community that often will bring a different perspective to the table. Yet, as we say in this country, the more things change, the more they remain the same. In the end, accident investigation will remain at the front end of accident prevention.

Before I close, I urge you to enjoy Florida while you are here. The Atlantic Ocean is just an hour away to the east, and the Gulf of Mexico is just an hour away to the southwest. In addition, of course, we have Orlando, which can keep you busy and entertained all week. You can start right here with the Disney property and work you way down.

Finally, ISASI extends its thanks to everyone who volunteered to put this seminar together. Special thanks go to Jamie Nichols and Antony Brickhouse, but we also thank those who worked on the Technical Committee, those who organized the Companions' Program, and those who handled the demanding work of sorting out the details for hotel rooms, catering, audio visuals, and the million other things that sponsoring a seminar like this demands. We extend our thanks to everyone.

I encourage everyone to thank members of the Committee whenever you have an opportunity to do so and, again, I encourage you to participate in the seminar, to learn and to share your knowledge while you are here, and, most of all, to enjoy the seminar. ◆

KEYNOTE ADDRESS
What Is Next?

By Deborah Hersman, National Transportation Safety Chairman

(Remarks presented by Chairman Hersman in her keynote opening address to the ISASI 2009 air accident investigation seminar delegates on September 15 in Orlando, Fla., USA.—Editor)

Good morning everyone. And a special konichiwa, guten morgen, ni hao, and bonjour to the International Council members and to our international attendees.

It is my privilege to kick off ISASI's 40th annual seminar. When preparing for my speech, I spent some time thinking about this year's theme "Accident Prevention Beyond Investigation." It is a theme that encourages us to ponder "What is next?" This is a room full of people who spend their time solving puzzles, putting the pieces back together to figure out what failed and how a design can be improved, or why people made the wrong decisions in the seconds before a disaster. So the theme is a great one, "What is next for you, for me, for us?"

Seven weeks ago today, I became the 12th chairman of the NTSB. Many of you, well, maybe most of you, don't know me, so let me give you a little glimpse of "what is next" for the NTSB during my tenure. There are three attributes that I believe are critical to the NTSB's mission and work. They are transparency, accountability, and integrity. Last week, I addressed the NTSB staff as a group for the first time. I challenged them, as I am challenging myself, to raise the bar in all three of these important areas.

Some of you may be wondering, "What's next for the NTSB's relationship with our international counterparts?" I believe some of the same themes crossover to the international arena. Today, in addition to transparency and accountability, I will also focus on cooperation.

For the past 5 years I have had the privilege to serve as a member of the United States National Transportation Safety Board alongside my colleague, Member [Robert] Sumwalt, who many of you know is a bona fide member of ISASI. During my time at the Board, I've accompanied our NTSB staff investigators on 17 major transportation accident investigations. These events have covered all modes of transportation: airliners, emergency medical service and sightseeing helicopters, business jets, private aircraft, light rail trains, freight trains, container ships, recreational boats, school buses, and motor coaches. Allow me to express my utmost respect for you—the professional air safety investigators and your peers who come from the various business and educational sectors associated with the transportation industry. I would like to recognize the NTSB investigators whom I have worked with in the audience—please stand (Bob MacIntosh, Frank Hilldrup, Joe Sedor, Lorenda Ward, and Scott Dunham)—and the many NTSB alumni here today. I have the privilege to be the public face for the work they do. Like these investigators, many of you have dedicated your careers to determining the causes of aviation accidents and coming up with solutions to safety problems encountered in your investigations.

Chairman Hersman, keynote speaker, opens her address by asking "What is next?"

Last night I had the opportunity to talk with [Truman] "Lucky" Finch, one of ISASI's founding members. I understand that this is ISASI's 40th annual seminar. And since the NTSB is just more than four decades old, I thought it might be worthwhile before we discuss what is next to look back at where we came from. Forty years ago, Embraer, Airbus, and Thierry were being conceived and birthed, as were Jimmy and David. Bombardier aerospace was just a glimmer in a snowmobile's eye. Forty years ago, Ron Schleede and Bill Hendricks will tell you they put together their accident reports by themselves using only their brilliant investigator skills, a legal pad, and a typewriter. Forty years ago, Bob MacIntosh has told me that we had to dial an operator to make an international call.

Today we are in a world that moves fast, communicates instantaneously, and demands answers immediately. Even though the NTSB's mission remains the same, the world around us has changed drastically. Therefore, we must constantly be asking ourselves, "What is next?"

Transparency

What is next for news media relations? I know many of you were here yesterday for the tutorials on the subject of news media relations, which included one of the Safety Board's public affairs officers. As many of you know, major accidents are not covered by just local or even national press, but more and more by international correspondents. Following a major accident, we recognize that the press has an insatiable appetite for information, and the public has an understandable curiosity about the event. Yet we must try to balance the equation of providing factual data to the public without speculating on the causes of the accident. You're going to hear me mention transparency, accountability, and cooperation several times this morning, and public relations is a perfect place to start. As an agency funded by the public, the NTSB fully embraces transparency and the public's right to know about our investigations. In fact, it is through the process of showing the public that we are conducting independent, thorough investigations that we derive our ability to influence decisions that are made following an accident.

If the NTSB, as the government's transportation accident investigation agency, does not provide credible information in a developing accident investigation scenario, other sources will attempt to fill the void. And in most cases, that void will be filled with information that is unreliable, unverified, and sometimes just plain wrong. Many of the people who talk to the news media have impressive credentials, and I do not begrudge them trying to explain to the general public highly technical situations. However, if their opinions are the only information the public receives in the days following the crash—and these opinions are rendered hundreds of miles from the scene—then the public will be ill served.

Even worse, depending on where the information comes from, it may be self-serving to the originator and damaging to the other participants in the investigation. For that reason, the NTSB spokesperson at the scene is the source of all publicly released factual information about the investigation. We try very hard to provide the public with reasonable details of the facts to assure them that the investigation is being conducted in a thorough and unbiased manner. In fact, many times we ask the public for support regarding witness information and other site details. Our purpose at an NTSB press briefing is not to provide the media with details to solve the accident, but rather to demonstrate to the public that the process of the safety investigation is being conducted in a professional manner.

President Obama has committed to making his administration the most open and transparent in history. While the NTSB is an independent agency, I believe the President's commitment is consistent with the NTSB's long history of open and visible investigations. The value we place on transparency in our investigations in order to meet the expectations of the public may be very different from the processes in place in other nations, including some that are represented here. In fact, you may *personally* disagree with our protocol, but it is hard to contend that the NTSB's open policy has not proven to be effective over time. For international participants in investigations within the United States, we have published ICAO differences in ICAO Annex 13 to keep all states advised of our policies regarding the release of factual information.

What's next regarding how we communicate with the public and our stakeholders?

The Internet and other electronic tools are changing and expanding at breathtaking speed. I would like to see the NTSB make better use of those tools to bring our message faster and with more content to the news media, to Congress, and, most importantly, to our stakeholders. Recently we took the step of opening our dockets to the public via our website. We not only hold our Board meetings and investigative hearings in full view of the public, but we webcast them so that anyone can watch. What this means is that these meetings are more transparent than ever before—available not just to stakeholders and the news media, but also to international viewers without any expensive travel costs or inconveniences.

This year our Office of Aviation Safety has already scheduled four investigative hearings, one on the safety of helicopter emergency medical services (2008 was one of the worst years on record for the HEMS industry, with nine accidents resulting in 29 fatalities), one on the US Airways dual-engine failure following an encounter with multiple Canada geese and subsequent forced landing in the Hudson River; one on the fatal Colgan accident in Buffalo, N.Y., on February 12; and finally, next week, I will be chairing a hearing on the Empire Airlines domestic cargo flight for FedEx that landed short of the runway in Lubbock, Tex., in freezing drizzle conditions.

While all of this work raises the bar on transparency, we aren't doing it alone. We had the participation of international representatives at each of our hearings. American Eurocopter and Canadian Helicopters were witnesses at our HEMS hearing. Airbus and EASA were witnesses at the Hudson hearing, with BEA serving as an accredited rep on our technical panel. Bombardier and Transport Canada sat as witnesses at the Colgan hearing, with the TSB serving on the technical panel as an accredited rep. And next week, we will be joined by ATR and EASA at the hearing on the Empire accident. Even though our system may be different from yours, we are working together to achieve a transparent and seamless aviation system, and we rely on the support we receive in our investigations from our partners that serve as accredited representatives, and those who represent labor unions, regulatory authorities, and manufacturers. Aviation is a global endeavor. If you take away one thing from my talk this morning, I want to make it clear that we recognize the value of working with and learning from our international counterparts—this is the only way that we will succeed. We are working together to accomplish this, so what's next?

I'd like to briefly touch on the other subject of the tutorials, criminalization. I can be brief and to the point. The NTSB's relationship with the U.S. Department of Justice is excellent and well established. Unless the Attorney General and I, as the chairman of the NTSB, agree that circumstances reasonably indicate that an accident may have been caused by an intentional criminal act, our NTSB investigators have unimpeded authority to conduct the investigation. The NTSB has priority over any judicial or other agency's investigation for aviation accidents. We control the accident site, and our investigators are free to pursue the fact-gathering process as necessary. We recognize that our position in accident investigations may be different from that of investigative agencies in other nations. Frankly, we are grateful that the U.S. Congress provided the NTSB with primary jurisdiction over most aviation accident investigations. However, we all have to work within the system that exists in the state of occurrence. This demands effective coordination and communication at every level of the investigation as well as understanding and respect for the conditions that our investigative counterparts are facing.

Accountability

When I asked our staff last week to raise the bar on our accountability, I know I was asking for a lot from a group of dedicated professionals whose work days are already very full. We investigate about 1,600 accidents per year. In 2008, the NTSB responded to 28 air carrier events; the 20 in scheduled service were all, fortunately, non-fatal. Last year our vehicle recorders laboratory received and read out more than 200 recorders. In addition, we received 178 foreign notifications of accidents or serious incidents involving U.S. operators or products. As a result, NTSB accredited representative teams traveled to 27 accidents in foreign countries to assist the local investigation authority.

Raising the bar on accountability will require the NTSB to be strong and nimble in its accident investigations in order to serve the American traveling public and to meet our international commitments. I would like to build on the technical strengths of our very competent professional staff to place our investigators at the forefront of technology. Certainly we will retain the investigative skills [needed for the] early-generation jet transports like the DC-9 and the B-737-200 and the Cessna, Beech, and Piper designs of the 1980s. As Frank [Del Gandio] mentioned in his opening, new technology is being assimilated into every sector of the aviation industry, like synthetic vision of a cockpit heads-up display and ADS-B for air traffic management. The aircraft coming off the production line are a new breed, filled with these innovations. Boeing, Airbus, Embraer, Bombardier, Gulfstream, and all the general aviation manufacturers now offer leading-edge technology, and engine manufacturers are satisfied only with the highest levels of efficiency in their new designs.

Implementing electronic flight control systems; optimized powerplant management; advanced composites; basic electrical and environmental engineering support systems; and navigation options, such as the electronic flight bag and surface moving maps, requires that our technical staff and other participating investigators are constantly learning to stay current with this technology. The rapid changes in technology provide challenges, but they also hold the keys to solutions we couldn't have imagined 40 years ago. So with respect to technology, it is very exciting to think about what's next.

In the past 5 years that I have served on the Board, I have noticed that today's fast-moving and capacity-filled environment demands that we do things with reasonable urgency. When I first started my professional career, we didn't have e-mail addresses, and if you had a phone, you needed to carry it in a bag and have an antenna for it. When I came to the Safety Board just more than 5 years ago, we had pagers. Today our blackberries can work internationally, and they provide us with content-filled messages and access to the web. All of these developments have enabled us to be more efficient and respond more quickly. But along with these improvements has come a commensurate expectation that we can work better, faster, and stronger. As we complete the field portion of an investigation, you will continue to see our investigators conduct component examinations as an immediate follow-on activity. We will communicate with participants to our investigation at Internet speed. We cannot accept weeks and months of reviews and slow-crawl responses as we complete each step in our investigative process. Similarly, when we identify a safety deficiency, we can't wait for a recurrence to address it. If the failure has been identified, documented, and analyzed, then what is next? Waiting for months to issue the final report? No—in some cases we may need to act quickly to issue a recommendation; so if the situation merits it, we will go forward with recommendations even before we complete the final report.

The NTSB has an obligation to alert the transportation community to acute safety problems, whether or not the problems may have played a causal role in the accident. Recommendations we issue during the course of an investigation do not signal that we have determined the cause of the accident. They simply point to a safety vulnerability that deserves immediate attention.

In recent weeks, we've issued recommendations on the still on-going investigations of the Hudson River midair collision, the crash of a corporate jet in South Carolina, and, in a surface mode, on the collision of two transit trains in Washington, D.C. I will continue to encourage such timely action by our investigative staff in the future.

I will also push recipients of our safety recommendation letters to raise their bar on their own accountability. We simply cannot accept "we're working on it" as a satisfactory response from a regulating agency about an identified safety risk. What we will accept is corrective action implemented and the risk mitigated—or at the very least, a clear forecast of when corrective action will be completed. I have been encouraged by new FAA Administrator Randy Babbitt's recent efforts to act quickly on safety problems. Just a couple of weeks ago, the FAA announced changes to the airspace in the New York area following the mid-air collision over the Hudson River last month. The Safety Board will analyze the FAA's action to see how closely they comport to our recommendations. But this is an example of the regulator asking, "What's next?" and then acting on the answers it received when it asked the question.

Can we attain a stronger and more nimble posture without affecting the quality of our work? Can we modernize without affecting the quality of our NTSB products? Yes, we can and we will. The 21st century is well under way, and it requires new thinking. We hear the chorus of support for the integration of Safety Management Systems (SMS) and a realignment of responsibility and accountability for operators as we move toward a more performance-based approach to safety. While we hope that SMS will prevent many accidents, we recognize there is a key role that accident investigation will continue to play in the identification and mitigation of safety deficiencies even in the SMS environment.

So what is next for us? While I am challenging staff members to increase their efficiency, I am also calling for continuous review by the management team—this is our own version of SMS. Our investigators have recently showed us that they are looking beyond causal factors. In a fatal Citation bird strike accident in Oklahoma City, they identified organizational and oversight failures that, while not causal, created a poor safety culture. In recent HEMS recommendations, we "followed the money" so to speak, and issued recommendations asking the government agency that controls reimbursement for HEMS operators to establish safety standards and audit operators. You should also know that we are also holding parties to our investigations accountable to their obligation just as we are being held accountable to our constituencies. Today, while I am here with you, Vice-Chairman Hart will be testifying on the Hudson mid-air collision before the Senate, and tomorrow morning I will be delivering the same testimony to the House. This reckoning on the status of our investigation comes approximately one month after I launched to the accident with our team. We must provide some answers to lawmakers' questions as they look to us with the question of "What's next?"

After watching our staff members in action for the past 5 years, I have every confidence they are up to the job, and I will support them in every way I can to raise the bar for both the NTSB and those who participate in our investigations. By ensuring that investigators maintain their technical competence, issuing recommendations as soon as they are warranted, and improving our internal processes, the NTSB will be a more nimble and more accountable organization.

Cooperation

Now to cooperation, coordination, and support between the NTSB and accident investigation authorities from other countries. Our partnerships with multinational organizations such as the European Aviation Safety Agency (EASA) and the Interstate Aviation Committee (MAK) of the former Soviet Union have provided many valuable contributions to worldwide safety improvements. Some of these improvements reflect directly on our U.S.-manufactured products. For example, we recently issued coordinated recommendations with the Spanish CIAAIC on the MD-80 takeoff warning system related to the Spanair accident in Madrid, with the U.K. AAIB related to the British Airways B-777 dual power loss at Heathrow, and with the Canadian TSB and MAK of Russia on the issue of the Cessna 208 flight in icing conditions.

It is no revelation to this body that aviation investigations are more and more becoming global affairs. The crash of Air France Flight 447 in June involved a multi-nation search effort. I will defer to Paul [Arsenault] to discuss their investigation tomorrow, but our support and good will are extended to both the BEA and the people who have lost loved ones in this accident.

I would also like to note that we have been participating for more than a decade with the U.S. Department of Transportation "Safe Skies for Africa" program. This initiative has now expanded into the ICAO Safety Roadmap in Africa and we remain fully engaged. We believe it is important to further our relationships with partners like EASA, MAK, and the regional safety initiatives around the world because these relationships are critical to teamwork, consultation, and cooperation necessary in every investigation and ultimately to the overall credibility of the ICAO Annex 13 process.

Before I close, I would like to say a word about the families of accident victims, our most vulnerable stakeholders. Since 1996, the NTSB has been charged by the U.S. Congress to coordinate federal resources for family members. At an accident scene, our Office of Transportation Disaster Assistance has developed a system with the airlines to provide a dedicated location for those family members to gather away from the prying eyes of the press, as well as a process to keep them informed on the progress of the investigation, even after we leave the accident scene. This has been a positive development, and we will endeavor in the next 2 years to further develop our relationships with family members and enhance our system of keeping them informed and also hearing what they have to say. I'm happy to see that other nations have been moving in a similar direction, and I sincerely hope that the trend continues.

This conference [ISASI 2009] is a perfect example of what the next 40 years hold for global aviation and accident investigation. Although the U.S. is hosting this year, more than half of the attendees are guests from 32 other nations. This forum is a great opportunity to meet with and work with your colleagues; I saw impressive signs of cooperation last night with Tom [Dolt] and Thierry [Thoreau] of rivals Boeing and Airbus putting their heads together and residents of China, Hong Kong, and Taiwan discussing aviation safety at the same table. All kidding aside, I have shared some of my priorities with you, so I ask our international partners, what's next, how can we support you?

In the news media we've been hearing much about civility—in the Congress, on the tennis court, but not here. To the international community, I would like to recognize your graciousness. As many of you know, last Friday was the eighth anniversary of 9/11. My first meeting that morning was with ICAO Secretary General Raymond Benjamin, then I met with a delegation of air safety officials from Brazil, and later in the afternoon I had a phone call with representatives of ATR (who will be participating in our hearing next week). One gentleman was French and the other was Italian. Each meeting was opened with an expression of remembrance and support (in English, I might add) for the American people on the anniversary of 9/11. This acknowledgement was appreciated and so considerate. Danke, tak farid, muchas gracias, mange tak, and thank you.

In closing, I would like to express my personal appreciation for the cooperation and support the aviation community has offered me. I am not an aviator, but I have been humbled by the many well wishes from each of you, as I know many of you care deeply about this agency I am entrusted with. Thank you for inviting me here today, and also for everything you've done to improve aviation safety around the world. I look forward to working with you during my term as chairman.

So, what do the next 40 years hold for ISASI and aviation investigations? Can we be more transparent, accountable, and cooperative? International borders still exist, but they, too, are becoming more transparent and are no longer boundaries. The Internet has connected us all. The world is preparing for the next flu pandemic that can travel through time zones as rapidly as an overnight package. The aircraft that bring us together, whether designed by Embraer or Airbus, are made with parts that are manufactured all over the world. The people who rely on you to do your work do not represent the U.S., South Africa, China, or Britain, they represent humanity. In the end, as leaders, as safety professionals, as human beings, we have been given a noble charge; we are our brother's keepers. I'm optimistic that, with your support, we can build on the enthusiasm and dedication fostered here to continue the historic period of air safety we've experienced, and to strengthen the ties of the international air safety community. ◆

LEDERER AWARD

Two Receive 2009 Jerome F. Lederer Award

By Esperison Martinez, Editor

The International Society of Air Safety Investigators (ISASI) has for only the second time in its 45-year history awarded its coveted Jerome F. Lederer Aviation Award to two recipients. Named as year 2009 recipients are Capt. Richard B. Stone and the Australian Transport Safety Bureau (ATSB).

The Award is given for outstanding lifetime contributions to technical excellence in furthering aviation accident investigation and achieving Society objectives. ISASI is an organization dedicated to enhancing aviation safety through the continuing development and improvement of air accident investigation techniques. To this end, its membership is made up of persons from 57 countries who are actively engaged in the investigation of aircraft accidents or in prevention activities that identify, eliminate, or control aviation hazards before accidents result.

Presentation of the Lederer Award is a major highlight of the Society's annual seminar. Generally, the recipient is announced on the opening day of the seminar; however, this year President Frank Del Gandio also broke from tradition and withheld the individual's name until the awards dinner banquet, held on the last evening of the seminar. Indeed Stone, himself, had no inkling of his selection. The ATSB, however, did have advance word of its selection to ensure that it would have a representative present to accept the Award. Still, none in the audience were aware that two parties had been selected.

With ATSB representatives Richard Batt and Stewart Ross on stage, President Del Gandio noted the Bureau's worldwide reputation for excellence, based on its operational independence, objectivity, and technical competence in accident investigation. He said its expertise and contribution to the field of human factors, at both the individual and organizational level, is acknowledged as world class. (Prior to 1999, ATSB's predecessor was the Bureau of Air Safety Investigation [BASI]. Herein both are referred to as the "Bureau.")

Del Gandio then went on to outline the Bureau's "lifetime" of achievements in this field. He said: "In 1983 the Bureau became one of the world's first civil aviation safety investigation organizations to recruit a human performance specialist. Subsequently, a core team of human performance specialists developed the Bureau's capability in human factors, systems safety, and research and was instrumental in fostering the role of human factors in Australian aviation safety. In 1989, the Bureau became the first aviation safety investigation organization to have a specialist human factors practitioner as its head. As a result, the Bureau became a world leader in proactive accident prevention and safety enhancement, as well as core accident investigation. Subsequently, the Bureau became more active in the International Civil Aviation Organization (ICAO), and in the 1990s was highly influential in the adoption by ICAO of the requirement for air safety investigations to include an examination of relevant organizational and management aspects, using the Reason model of systems safety as a guide.

"Since the mid-1990s, all Bureau investigators have received human factors awareness training as a component part of their professional development. This quality course has continued to be enhanced and is highly sought after by external participants worldwide. Bureau personnel are currently delivering human factors training in Indonesia as part of the Indonesia Transport Safety Assistance Package (ITSAP).

"Further, the Bureau was the first accident investigation body worldwide to incorporate the formal analysis of human and organizational factors into standard investigation methodology. It did this in its 1993 investigation report into a near collision between a DC-10 aircraft and an A320 aircraft in 1991 at Sydney Airport and in its 1995 report of a fatal CFIT accident in 1993 involving

E. MARTINEZ

Award recipients are shown left to right: Capt. Richard B. Stone, Richard Batt, President Del Gandio, and Stewart Ross.

Monarch Airlines. These reports outlined the Reason model to highlight the role of systemic factors in the development of the occurrences. The Monarch Airlines report was a catalyst for major structural changes within the then Civil Aviation Authority.

"In 2003, the Bureau's report into Ansett maintenance safety deficiencies and continuing airworthiness issues worldwide was awarded the 2003 Flight Safety Foundation Cecil A. Brownlow Publication Award 'for a significant contribution to aviation safety awareness.' This report reinforced the concept of 'organizational mindfulness.' While the Bureau has since adapted the Reason model to better suit its purposes, the use of this methodology's principles continues to underlie all investigation analysis and report writing.

"At the same time as the Bureau was developing modern methods of investigation analysis, it was also producing world-class research reports. Two such reports received the Chartered Institute of Transport in Australia's Qantas Award for Transport Excellence. The first report to receive this Award was the *Limitations of the See-and-Avoid Principle* (1991). The second was the *Human Factors in Aircraft Maintenance* report (1995).

"From its inception as a multimodal agency on July 1, 1999, the ATSB has continued to develop and apply improved methods of accident investigation and analysis to enhance transport safety in Australia and internationally. The ATSB website, with more than 1 million new users and 40 million 'hits' in 2008, is a testament to the Bureau's influence.

"The quality of a safety investigation's analysis activities plays a critical role in determining whether the investigation is successful in enhancing safety. However, this has been a neglected area in most organizations that conduct safety investigations. One of the Bureau's leading human factors specialists tackled this professional void and, through a process of benchmarking and wide consultation, has developed a rigorous best-practice analysis framework for transport safety investigations. This approach is detailed in the Bureau's 2008 publication *Analysis, Causality, and Proof in Safety Investigations* and is a fundamental functional element of the Bureau's Safety Investigation Information Management System, introduced in 2007. Both have attracted the significant interest of the chairmen and CEOs of independent investigation body members of the International Transportation Safety Association (ITSA).

"The Bureau's ongoing commitment to the behavioral science of human and organizational factors in transport safety is at the heart of its credibility and underlies its reputation as a leading safety investigation agency in the world arena. This reputation has enabled it to contribute strongly to the amendments to Annex 13 recommended by the 2008 ICAO AIG Divisional Meeting and also to a new code for international marine investigation agreed to at the IMO in 2008 and increasingly to rail safety investigation."

In accepting the Award, Richard Batt said: "It's my great honour to accept this Award on behalf of the Australian Transport Safety Bureau. It is a particular honour to accept the Award as it commemorates the remarkable life and safety achievements of Jerry Lederer, and it is a particular honour given the past recipients of the Award, both individuals—some of whom are here this evening—and organizations.

"As we know, in any air safety investigation the crucial first step is a thorough operational and technical investigation to establish what happened in the accident or incident, but it is typically only by then looking at human factors—at both the individual and organisational level—that we can understand how and why the accident or incident occurred.

"More than 20 years ago, Dr. Rob Lee, a human factors specialist, was appointed as director of the Bureau—the first time anywhere in the world that someone with a human factors background had been appointed to lead a national civil aviation safety body. And from that time, under successive directors, human factors has been a prime focus of the ATSB. I think it is interesting, when we reflect on the many excellent presentations we have seen this week, how many of them have had a human factors theme.

"So, on behalf of the ATSB, I would like to express our sincere appreciation on receiving this year's Jerome F. Lederer Award."

The seminar delegates showed their agreement with ATSB's selection with a thunderous and standing applause. And as the banquet hall quieted, President Del Gandio said into the microphone, "Will Capt. Dick Stone please join me up here." It was only then that Stone and the audience learned that there were two recipients of the Lederer Award. Surprise was evident in Stone's demeanor, as was the gratitude he was

Lederer Award Selection Process

Presentation of the Jerome F. Lederer Award is the culmination of a thorough consideration of a nominee's experiences by the 12 member ISASI Awards Committee, chaired by Gale Braden. The selection task is not taken lightly and involves multiple steps that begin with an early announcement of the open nomination period, which begins with the close of the annual seminar and goes through May 31 of any given year.

Chairman Braden shares the selection process steps in the hope that it will entice a greater number of nominations for the prestigious Award. He urges members to begin their nomination consideration now and to watch for the nomination submission procedure in the January-March issue of the *ISASI Forum,* which is also available on the ISASI website. From time to time, through the *Forum,* he reminds the membership of the opportunity to submit nominees.

"When I receive a nomination letter, I evaluate it against the criteria and accept or reject it. If I reject it, I respond to the nominator and explain the reason for the rejection. Most often the rejected letters fail to discuss any degree of accident investigation activity. After explaining that accident investigation is the focus of the Award, the nomina tor will often rewrite the letter and make it acceptable.

"Our Committee consists of 12 members, including the chair. Six are from the USA and six are international. When the nominating season closes, I copy each letter and add a notation to it indicating if it is a 1st, 2nd, or 3rd consideration. I then mail it along with a ballot listing each nominee, a copy of the selection criteria, and a cover letter to each member reminding them to vote for three nominees by placing a 1, 2, or 3 beside their name on the ballot.

"The votes are weighted in the following manner, a number 1 vote is worth 5 points, number 2 is worth 3 points, and number 3 is worth 1 point. Thus, each member's vote is worth 9 points spread over any three nominees. When there are three or more nominees, a tie is almost impossible; but with only two nominees, a tie can occur. In such cases, the ISASI president has the prerogative of casting a tie-breaking vote. In both instances in which a tie vote occurred, the president determined both parties were deserving and allowed the multiple presentations."

The scoring criteria for selection used by Committee members follows:

- Selection of award recipient: Emphasis should be placed on original and remarkable contribution and personal effort beyond normal duty requirements. Mechanics, engineers, and others not at the top administrative or research levels should be considered for any outstanding contributions to accident investigation. The nominee's manner of operating, the duration and persistence of his (her) efforts, and his (her) standing among peers shall be considered. A nominee shall not be eliminated because of lack of popularity. Nationality, creed, sex, or race shall not be considered.
- In general, the contribution should be important to aviation safety, or if from another field of safety endeavor, one that could be applied to the aviation field.

Advancement should be clearly attributable to the person or associated group nominated (in case of many developments, it is often difficult to determine an individual who is responsible.)

- The dedication of the nominee to safety and aircraft accident investigation is a guiding criteria, such as his (her) imagination in working beyond the requirements of his (her) job to direct his (her) efforts to safety and accident investigation on his (her) own initiative. These efforts may be multifaceted.
- The contributions should have relatively broad application to the investigative area and may stem from a particularly effective manner of pursuing accident investigation objectives. The contribution need not be of recent origin so long as it has improved accident investigation. ◆

feeling for the honor bestowed upon him by his peers.

President Del Gandio continued, "Capt. Stone is more than qualified to be a recipient of the ISASI Jerome Lederer Award owing to his outstanding contributions to technical excellence in aircraft accident investigation.

"He began his aviation career more than five decades ago as a U.S. Air Force pilot and began his civil aviation career with Northeast Airlines in 1957, which was later absorbed by Delta Air Lines, from which he retired in 1992. He has remained active in aviation as a consultant for various government and industry aviation interests until the present day.

"Throughout his civil aviation career, Capt. Stone was deeply involved in aircraft accident investigation and prevention for the Air Line Pilots Association (ALPA) for more than two decades, most of which was performed as a volunteer. His strong interest in human factors led him to establish ALPA's Human Performance Project in 1977. He was a member of the ALPA National Accident Investigation Board

(1977–1987), chairman of the ALPA Human Performance Technical Committee (1983–1987), and chief accident investigator for the Delta Air Lines Master Executive Council (1984–1987). He also served as ALPA's executive chairman for aeromedical resources for many years.

"He has been as deeply involved with ISASI, joining us in July 1969, and has been extremely active in its programs every since. He has served as the ISASI U.S. councillor (1984–1988), ISASI president (1994–1996), ISASI Executive advisor (1996–present), and chairman of the ISASI International Working Group on Human Factors (1996–present). He became a Fellow of ISASI in 1994. As Executive advisor, Capt. Stone has provided extremely valuable guidance to the ISASI Council and acts as the ISASI news media spokesman.

"Capt. Stone represented ISASI at the International Civil Aviation Organization (ICAO) Accident Investigation and Prevention meeting in Montreal, Quebec, Canada, in 1999 (AIG/99). He also assisted the ISASI team with developing its input to the ICAO AIG/08 meeting in 2008 and has also participated as an instructor for ISASI Reachout workshops.

"He was the general and program chairman for the 1987 ISASI annual international seminar held in Atlanta, Ga., and will duplicate that position for ISASI 2011 to be held in Utah. He has served on several technical committees on various aviation safety topics, including human factors, and he has presented several technical papers before a wide variety of audiences, including testimony before the U.S. Congress. In summary, Capt. Stone exceeds all of the requirements to be honored with the Jerome Lederer Award."

The audience agreed and welcomed Capt. Stone to the lectern with great applause.

In his soft-spoken voice, he said: "I am humbled by this Award, especially since it has Jerry Lederer's name on it. Thanks to the folks who, somehow, unearthed my experiences and put them on paper in sufficient order to gain this honor.

"When I look out at this audience I see many investigators I have worked with. They are some of my best friends. What we have in common is a strong connection to ethics in accident investigation.

"I ran into this principle in one of my first accident investigations. I was helping the Mohawk pilots who were an interested party in the Nov. 11, 1969, FH-227 accident at Glen Falls, N.Y. Each night the pilot investigators gathered to share their findings that day. Before the meeting two of the Mohawk investigators approached me with concern. They had found a pilot's flight bag in the wreckage and it contained some medications. They had hidden the bag in nearby woods and wanted to know what to do about it. I said, 'We ought to talk to the other pilot investigators about it.' When the subject was out in the open at our meeting, I asked, 'What are we doing as investigators here?' They quickly responded that we were here to try to prevent similar type accidents. I asked, 'Would hiding the bag help in finding the cause of the accident?' They all agreed that the proper action was to bring the bag into the accident investigation.

"After the bag was bought in and thoroughly searched, it was determined that it belonged to a passenger who was a physician. I was very proud of these pilot investigators who realized that all facts must be brought before the accident investigation body if we are to protect safety of flight operations.

"Thank you all for selecting me to receive the Lederer Award." ◆

Past Lederer AwardWinners

1977—Samuel M. Phillips
1978—Allen R. McMahan
1979—Gerard M. Bruggink
1980—John Gilbert Boulding
1981—Dr. S. Harry Robertson
1982—C.H. Prater Houge
1983—C.O. Miller
1984—George B. Parker
1985—Dr. John Kenyon Mason
1986—Geoffrey C. Wilkinson
1987—Dr. Carol A. Roberts
1988—H. Vincent LaChapelle
1989—Aage A. Roed
1990—Olof Fritsch
1991—Eddie J. Trimble
1992—Paul R. Powers
1993—Capt. Victor Hewes
1994—U.K. Aircraft Accidents Investigation Branch
1995—Dr. John K. Lauber
1996—Burt Chesterfield
1997—Gus Economy
1998—A. Frank Taylor
1999—Capt. James McIntyre
2000—Nora Marshal
2001—John Purvis and the Transportation Safety Board of Canada
2002—Ronald L. Schleede
2003—Caj Frostell
2004—Ron Chippindale
2005—John Rawson
2006—Richard H. Wood
2007—Thomas McCarthy
2008—C. Donald Bateman
2009—Capt. Richard B. Stone and the Australian Transport Safety Bureau

Closing the Gap Between Accident Investigation and Training

By Michael Poole, Executive Director and Chief Investigator, and
Lou Németh, Chief Safety Officer, CAE Flightscape

***Mike Poole** is a professional engineer with a current pilot's license and is recognized as an expert in the field of flight data analysis. He represented Canada as the national expert panel member to the International Civil Aviation Organization's Flight Recorder Panel. He started in the field of aircraft accident investigation in 1977 and worked for more than 20 years with the Transportation Safety Board of Canada. For the last 15 years of his career at TSB, he was the head of the flight recorder and performance laboratory, which he developed for the Board. He was the Flight Recorder Group chairman on all major accidents in Canada as well as several international accidents. In 1985 he was responsible for initiating and driving the development of the Recovery Analysis and Presentation System (RAPS) for flight data analysis, which he successfully commercialized from the TSB in late 2001 to Flightscape. Mike co-founded Flightscape and is a now a member of the executive management team at CAE Flightscape, after CAE acquired Flightscape in August 2007.*

Photo
not
available

***Lou Németh** is the chief safety officer (CSO) for CAE's ab-initio, helicopter, business, and commercial aviation training business. He joined CAE after a distinguished 26-year career at US Airways where he served as a line pilot, instructor pilot, pilot training manager, and courseware developer. He has accumulated more than 25,000 hours of flight time and is type rated in nine commercial and business aviation jet aircraft. He served as director of flight operations for Flight International, the world's largest Learjet operator. Lou is a graduate of Embry-Riddle Aeronautical University and has continued to serve the University as a trustee and member of the President's Advisory Board. Lou is a recognized industry author, safety advocate, inventor, and speaker on the application of technology to pilot training.*

Abstract

We use full flight simulators to train pilots to fly airplanes and to carry out emergency procedures fastidiously. But do we, can we, should we also train pilots to *prevent* accidents?

Intimacy with accident investigations and/or or serious FOQA events results in intimacy with many of the often subtle factors and human factors issues that can ultimately culminate in a catastrophic outcome. While written accident reports supply a wealth of information, their shortcoming is that they are time consuming to read. More importantly, people often read the same sentence yet have a very different understanding of the sentence. There is arguably a gap between accident investigation and simulator training in that the problems we typically see in training are often not the same problems that cause accidents or that we see in daily FOQA program results. This paper will explore a few accidents to demonstrate how improved intimacy about what happened based on objective flight data may benefit flight safety. As expert observers of cockpit behavior, instructor pilots have a unique skill of reliably predicting the outcome of even small omissions or lapses in procedures. This instructor skill comes naturally as a function of observing crews practicing skills over and over again. This same instructor skill, as acquired through persistent analysis of crew behavior, is now extended to all crewmembers through flight data animation visualization and analysis tools. These technologies can communicate subtle causal factors effectively and consequently enable instructors to improve scenario-based training.

In addition to using flight data to develop enhanced scenario-based training, applying FOQA concepts to the full flight simulator will enable airlines to cross reference problems encountered in simulator sessions with problems encountered in daily flight operations. Using flight data from the simulator session to objectively measure and report on the training pilot's performance allows the instructor pilot to focus on the subjective human factors aspects of the flight operation.

Understanding how seemingly benign events can lead to catastrophic situations is paramount to changing attitudes and vigilance in the cockpit. Augmenting simulator training to replicate real-world situations based on improved intimacy with the sequence of events beyond the investigation report and beyond the statistics of FOQA programs promises to bring accident prevention to a new level.

The following accidents are examples cases where the authors of the paper were directly involved in the flight recorder analysis and consequently has firsthand knowledge of the details of the accident sequence beyond what is ascertainable from the written reports. The authors believe that this level of intimacy can be more readily gleaned through the use of flight animations and the use of flight data to develop full flight simulator training scenarios.

Saab 340 accident example

On Jan. 10, 2000, a Saab 340, HB-AKK operated as Crossair 498, crashed shortly after takeoff from Zurich's Runway 28 during night IMC. The aircraft was destroyed, and all 10 persons on board were fatally injured. The Swiss Aircraft Accident Investigation Board requested the assistance of the Transportation Safety Board of Canada (TSB) with the readout and analysis of the FDR and CVR. Approximately 50 parameters were recorded on the aircraft's solid-state FDR, and 30 minutes of good quality audio were recorded on the aircraft's CVR.

The Swiss AAIB IIC originally requested a "readout" of the recorders. Consequently, the TSB prepared printouts and graphs of the flight data along with a transcript of the audio, which the IIC intended to take back to Zurich to conduct the analysis. People intimate with the process of recovering flight data realize that the

Figure 1. Saab 340 accident site.

original data are a sea of binary 1s and 0s that need to be converted into meaningful engineering units. Many investigators believe that flight data are "factual," but the process to convert the data is fraught with the opportunity for error. Engineering conversion formulas, documentation, wiring, acquisition unit programming, software used to convert the data, timing issues, resolution issues, replay options, etc., will all affect the quality of the outcome. In fact, if the same source binary flight data are replayed with two different replay systems, it is highly *unlikely* that the same results will be produced.

The data revealed that shortly after takeoff the aircraft, in night IMC, entered an increasing right turn apparently consistent with control inputs. As a flight data analyst, when you see this type of data, you immediately start to question if the data are being processed properly or are working properly (in this case if sign conventions are correct) because on the surface, the sequence does not appear to make sense. The TSB started to work on a flight animation immediately, in an effort to understand if the data were properly processed because animations are an excellent means to validate the correct behavior of numerous interdependent parameters. The level of "validation" of any given parameter should be proportional to what you intend to conclude. If you are putting a lot of weight on a given parameter, it is natural that you would check its validity more so than if it were a less important parameter. The IIC noticed the TSB was working on an animation and asked if it would be OK if the investigation team was brought to Ottawa to analyze the data interactively using the animation as opposed to trying to analyze printouts and plots. Indeed, in this particular investigation, the early animation with the audio and transcript synchronized was very useful to conduct the analysis of the data and greatly expedited a common understanding of what likely happened. The Swiss team came to the TSB and spent a few very fruitful days developing and studying the animation.

Animations have two very distinct purposes. One is to assist in the analysis process and one is to communicate the findings. Often the display choices are different for each of these purposes. Some authorities still view animations as having little or no analytical value and use them only for communication purposes. But in the case of this accident, the animation had tremendous analytical value and it would have been much more difficult to understand the sequence of events and gain confidence in the data quality without it.

It is not the intent of this paper to go into the details of this accident; however, the key points related to the subject of this paper are as follows. The pilot flying (commander) became disoriented,

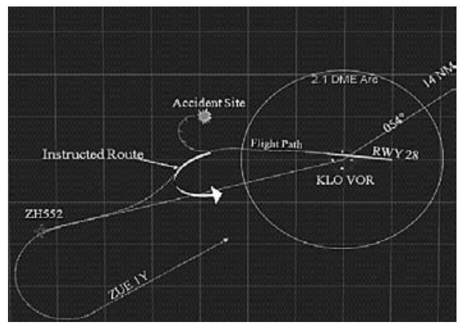


Figure 2 (above). Flight animation developed by the TSB to support the investigation team (courtesy the TSB). Figure 3 (left). Planned route, instructed route, and flight path to crash site.

essentially believing he was in a left turn when in fact he was in a right turn. During the standard instrument departure (SID ZUE 1Y), ATC issued a change in clearance, essentially cutting the SID short, and instructed the pilot to make a turn direct to VOR ZUE. The first officer confirmed by radio stating "turning *left* to Zurich East." The SID calls for a left turn as shown in Figure 3. The first officer reprogrammed the LRN (long range navigation system) from the present position to ZUE. At this point in the flight, the aircraft was more or less 180 degrees in the opposite direction of ZUE. When reprogramming the LRN, if the operator does not explicitly select left or right, the LRN will choose the turn direction offering the shortest distance. It just so happens that the aircraft was a few degrees closer to a right turn at this point and it was apparent that the first officer inadvertently programmed a right turn by not explicitly selecting left. With both crewmembers believing they were to turn left and both crewmembers believing the flight director was programmed for a left turn, when watching the animation with the CVR transcript integrated, it becomes relatively easy to understand how the commander could become disoriented and roll the aircraft into a right turn into the ground. To further validate this early theory in the investigation, the TSB derived the theoretical behavior of the command bars (since this was not a recorded parameter) and displayed them in the animation, which further supported the supposition that the commander became disoriented.

The Swiss AAIB report makes several excellent safety recommendations to prevent a recurrence. While the Swiss report is very thorough and filled with excellent safety information, it is still questionable as to whether this accident or similar accidents in which the crew is essentially "tricked" into a situation by a series of seemingly harmless events will effectively be prevented in the future. To the

Figure 4. Undercarriage from A310 accident.

authors' knowledge, there is no simulator training whereby crews are exposed to the sequence of events identified in this accident. Even worse, there are many flight crews who have no knowledge of this accident or the specifics of what caused it. The safety community has benefited from the lessons learned from this accident, but are flight crews flying similar equipment benefiting from the lessons learned? The current approach is for the safety community to learn the lessons and implement changes by way of recommendations, but it would arguably be much better if the crews could learn the lessons directly by exposing them to the sequence in the simulator environment.

Airbus A310 accident example

On Jan. 30, 2000, an Airbus A310 registered as 5Y-BEN, crashed shortly after takeoff from Runway 21 in Abidjan in night IMC. The aircraft's flight data recorder and cockpit voice recorder were brought to TSB Canada for readout and analysis. The aircraft's FDR recorded alternating streams of steady 1s and 0s indicating the flight data acquisition unit (FDAU) had malfunctioned and was sending erroneous data to the FDR. The CVR was of good quality and, although cryptic to determine the sequence of events, eventually enabled the investigation team to piece together what happened. Although there was no flight data available for this investigation, it is perhaps a good example of a case in which the crew was essentially "tricked" and flew the aircraft into the ground without ever understanding the problem.

The aircraft's stall warning system activated on liftoff, which surprised the flightcrew members. As they attempted to diagnose the problem, the flying pilot instinctively pushed forward on the control column to eliminate the stall condition. However, the aircraft was not in a true stalled condition and in less than one minute the aircraft was essentially flown into the sea. It was concluded that one of the angle of attack vanes must have been damaged causing the aircraft stall system to trigger as soon as the weight on wheels logic went to "air." No amount of forward control input could avert the stall (stickshaker) condition. Simulator tests confirmed that the only way to reach the crash site was to fly the aircraft in an "unstalled" condition.

The French BEA wrote a detailed report on this accident, but the question again comes up—have we done enough or what more can be done to ensure there is not a repeat of this accident? As with the previous example, the authors know of no scripted simulator training in which crews are given a false stall warning on liftoff in night IMC to see how they react to this real-life known situation. Given the same circumstances, it is probable that many crews would react the same way as the crew in question did, so it is arguably a matter of time before this accident repeats itself.

B-727-200 accident example

On July 7, 1999, a B-727-243F registration VT-LCI, crashed in Kathmandu into the Champadev hills at 7,550 feet approximately 5 minutes after takeoff in IMC. The accident was investigated by the Ministry of Tourism and Civil Aviation of the government of Nepal. No report from the government of Nepal could be found searching the Internet; however, the following was found on the NTSB website:

"*The investigation determined that the probable cause of the accident was the failure of the flight crew to adhere to a standard instrument departure (SID) and the failure of the controllers to warn the flight of terrain. Contributing factors were determined to be an incomplete departure briefing, unexpected airspeed decay during the initial climb, inadequate intra-cockpit crew coordination and communication, and the slow response to the premonition given by the air traffic controller.*"

The flight recorders were replayed at the TSB Canada. In this accident, the crewmembers were a little late in carrying out a right turn as required by the SID and was consequently flying toward mountainous terrain. When they realized they were late, they immediately began a right turn to regain where they were supposed to be. During the right turn, they received a GPWS warning—pull up. Instead of executing the escape maneuver in response to the GPWS, which requires a wings level maximum climb, they increased their turn radius to the right. In this case, given they knew they had made a mistake and had just corrected the mistake, it is understandable that when confronted with a GPWS their instinct was to tighten the turn rather than execute an escape maneuver. How many crews would do the same thing in the same circumstances? Is this accident also a matter of time before it repeats itself? Simulator training replicating this sequence for pilots frequently flying in the airports with mountainous terrain might go along toward reinforcing the need to carry out an escape maneuver in all cases.

Closing the gap

All three of these cases exhibit similar human factors problems in that the crew did not correctly diagnose the problem and/or did not respond in a way that would have avoided the accident. In all cases, the crewmembers were competent, well-trained, and representative of the industry. It can be argued, however, that their response was understandable, which means another crew confronted with the same scenario may well respond the same way. There have been numerous similar accidents in which crews did not respond the way trained. It is the authors' opinion that this is in part because the training environment does not replicate real-world scenarios such as the three examples presented. One reason that the training environment does not replicate real-world scenarios like this is because the people developing the training simply do not know the intimate details of the accident sequence, having not been involved in the investigations. The same logic can apply to serious FOQA events. It really does not matter if the aircraft hits the ground or not in the end. FOQA events of high potential for safety action need to be investigated and well understood and ideally used to develop simulator training scenarios if we really want to prevent them from becoming an accident.

Flight animations have the ability to disseminate complex information in a highly intuitive and entertaining manner in a fraction of the time it takes to read a report. Like any good movie, you tend to pick out details that you did not see before, each time you watch the movie. Written reports also do not lend themselves to assessing timing issues, while animations provide an immediate sense of timing, which can be important to the overall understanding of the accident. Finally, flight animations are an excellent means to communicate *what* happened to a wide cross-section of people. Without consensus as to *what* happened, there is little point of trying to understand *why* it happened. Further, the *what* happened is exclusive in that there are only one set of facts. The *why*, on the other hand, is not exclusive. For every *what,* there are many opinions as to *why*, and there is not necessarily a right answer. Despite the best efforts of the investigation community, unless you investigated the accident, many people simply do not know the intimate details of the accident as it is impractical to glean this level of intimacy from a written report. Flight animations have a unique ability to quickly communicate *what* happened, which greatly facilitates determining *why* it happened and more importantly, how to prevent it from happening to you.

Simulator training today largely focuses on how to fly the aircraft and how to respond to an emergency. It has not progressed to "evidence-based" training in which we use objective flight data to develop explicit scenarios from known accidents, incidents, and FOQA events. If you ask a simulator instructor pilot for a list of problems training pilots experience in the simulator, you will discover that there is little or no correlation to the list of problems that are known to cause accidents. This suggests that there is a gap between the flight safety community and the training community and that there is benefit from a much closer relationship than exists today in many airlines. It is timely for the industry to look at ways to improve the ability for the training community to exploit lessons learned by using actual flight data as the objective common base between the two communities. Coincidently, IATA within its ITQI (IATA Training and Qualifications Initiative) is actively exploring flight data from FOQA programs from volunteering airlines in an effort to change the regulations regarding simulator training to allow for evidence-based training. The following is an extract from the ITQI 2008 report from IATA's website:

"Progress in the design and reliability of modern aircraft has prompted an industry review of pilot training and checking requirements. In addition to the wealth of accident and incident reports, flight data collection and analysis offer the possibility to tailor training programs to meet real risks. The aim is to identify and train the real skills required to operate, while addressing any threats presented by the evidence collected. The IATA best-practice document will facilitate regulatory change and enable more efficient, safety driven, and cost-effective training."

Simulator brief-debrief

The TSB Canada was one of the first (if not the first) in the world to use mini-computer technology to animate flight data in a true 3-D environment for the purpose of understanding and communicating an accident sequence. This same technology has been applied for some time to the simulator community in which flight animation is used to replay "flight data" from the simulator to debrief the flight crew after the session. CAE is actively pursuing applying FOQA concepts to the full flight simulator whereby the analysis software

Figure 5: Simulator session animation replay using the same core technology as the accident investigation replay (courtesy Oxford Aviation).

provides automatic reports of problem areas in the flight, such as out of sequence procedures, incorrect procedures, missed or late procedures, etc. This allows the instructor pilot to focus attention on the more subtle human factors aspects of the simulator sessions. The simulator brief-debrief system currently under development at CAE to achieve the "close the gap" philosophy has the following key attributes:

- Simulator replay uses the same core animation analysis software that was developed for accident investigation and FOQA event animation, which allows for the replay of accident and/or FOQA animations directly on the debrief system to enable instructors to develop evidence-based scenarios. Simulator sessions can also be replayed by the FOQA animation system fostering increased collaboration between training and safety departments within the airlines.
- Interface from the FDR/QAR replay system to drive CAE full flight simulators with recorded flight data to replay accidents or serious FOQA events in the full flight simulator.
- Simulator record session control by the instructor to mark events of interest for quick navigation as well as potential for real-time notification of problems during the simulator session.
- Automatic report of problem areas during the replay.
- Ability for the crewmembers to have an electronic copy of their session plus real aircraft replay for self-study.
- Collection of data (with appropriate security and airline approvals) across simulators to study regional differences.
- Ability to begin to compare simulator session "flight data" to aircraft flight data to compare and ensure that simulator training continues to evolve to reflect real-world scenarios (evidence-based training).
- Video and audio synchronized with the replay of the simulator flight data.

Summary

Many people in the accident investigation business see the same core human factors issues over and over again. A combination of individually benign events led to a situation "outside the box" of current simulator training. It is, of course, impossible to train for every scenario possible but it is technically possible to train using objective aircraft flight data from past accidents and serious FOQA events. Evidenced-based training scenarios need to be developed using objective flight data to ensure pilots appreciate the need for vigilance, communication, and a strong safety ethic.

Many pilots read the accident headline and conclude that this would not happen to them; that the pilots in question were not doing a good job. If these same pilots participated on the investigation, they would undoubtedly conclude that this could happen to them as well since they begin to appreciate the subtleties of the sequence. Any pilot who works for a year at a safety investigation authority comes out of that experience with a real appreciation for what really causes accidents and is a safer pilot for it.

We cannot afford to send all the worlds pilots for a one year sabbatical at an investigation agency. What we can do is give these same pilots and instructor pilots easy access to flight data from accidents and serious FOQA events ideally in the form of interactive flight animations so that they can appreciate the intimate details of what went wrong. We can include simulator brief and debrief using actual flight data as an integral part of the training process, not an option. We can train instructors to leverage the technology to the benefit of the safety of flight. This will facilitate the creation of evidence-based training and allow the industry to better correlate problems identified through investigation and FOQA programs to problems encountered during flight simulator sessions.

The main problems in the simulator are typically not related to reasons why airplanes crash. This is because we still train to regulatory requirements and to carry out emergency procedures. This is not to say we should no longer do this. The more the real aircraft data and the simulator data match in terms of problem areas, the more we will know that we are closing the gap between accident investigations and training. ◆

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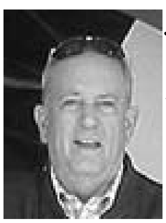
How Significant Is the Inflight Loss of Control Threat?

By Capt. John M. Cox, FRAeS, and Capt. Jack H. Casey, FRAeS,
Safety Operating Systems, L.L.C., Washington, D.C.

Capt. John Cox*, retiring from the airlines after flying 25 years, founded Safety Operating Systems, a Washington, D.C.-based aviation safety consulting firm. He has more than 14,000 flying hours with more than 10,000 in command of jet airliners. He holds an airline transport pilot certificate with type ratings in the Airbus A320 family, the Boeing 737 family, the Fokker F28, and the Cessna Citation. Cox is a Fellow of the Royal Aeronautical Society. He served as an air safety representative for the Air Line Pilots Association for more than 20 years, rising to the position of Executive Air Safety Chairman, ALPA's top safety job. ALPA awarded him its highest safety award in 1997. The Guild of Air Pilots and Air Navigator presented him with the Sir James Martin Award for aviation safety in 2007. He is an experienced accident investigator, having been involved in 13 major investigations (the best known being the USAir 427 accident in Pittsburgh in 1994) and numerous smaller investigations. He holds an air safety certificate from the University of Southern California.*



Jack H. Casey *spent the 8 years prior to becoming a partner at Safety Operating Systems as the pilot liaison for Embraer Aircraft Holdings, Customer Services USA, achieving a reputation as a worldwide expert in Embraer aircraft and their operations in line service. Since leaving military service in 1975, he has been employed with airlines and has flown the BE18, DC-3, B-737 and has flown more than 11,000 hours and 2.8 million miles without accident. During his career, Casey has served in all air carrier required positions, been a designated examiner, type rating examiner, and line check airman and gained considerable experience with the FAA, the NTSB, and numerous foreign regulators.*

This document reflects the ground-breaking work contained in the Federal Avaition Administration's (USA) Flight Upset Recovery Document Revision 2. It is consistent with the content and recommendations of that document, in addition to industry best-practice standards.

At all times manufacturer recommendations for proper aircraft operation are controlling.

Introduction and history

Airplane manufacturers, airlines, pilot associations, flight training organizations, and regulatory agencies are increasingly concerned with the incidence of loss of control events. Accidents resulting from loss of airplane control have, and continue to be, major contributors to fatalities in the commercial aviation industry. In fact, because of the decline of controlled flight into terrain (CFIT) accidents due to technological breakthroughs, loss of control has become the No. 1 cause of hull losses and fatalities in the worldwide air carrier fleet *if TAWS is functional.*

Resources are finite in any business. Industry safety professionals are tasked with determining the primary issues of concern, then addressing them in a planned and forthright manner with objective data and professional guidance. This is very difficult within a larger society that often decides issues with subjective data at best, "feelings" at worst. Data clearly establish loss of control flight upset (LOC-I) as the primary danger today in flight operations. Compare this with the news media interest regarding runway incursions that has driven FAA activity, rulemaking, and expense. A glance at the objective data establishes that, while runway incursions are a concern, as an issue it pales compared to loss of control.

Industry statistical analysis shows 22 inflight, loss-of-control accidents between 1998 and 2007. These accidents resulted in more than 2,051 fatalities. (*Airplane Upset Recovery Training Aid, Revision 2*). Data also suggest an even larger number of "incidents" in which airplanes experienced near or actual loss of control and qualified as upsets. There are several reasons such events occur: flight control problems, environmental dangers, equipment, and pilot inattention or inaction. Investigation of pilot actions during these events suggest pilots require specialized training to cope with airplane upsets. Research indicates most airline pilots rarely experience airplane upsets during their flying careers. It also indicates that many pilots have never been trained in maximum-performance airplane maneuvering, such as aerobatic maneuvers. Additionally, those pilots who have been exposed to aerobatics lose their skills as time passes unless such flying is a consistent hobby or second career.

This does not suggest training in aerobatics, although such training does improve an assortment of pilot skills. Indeed for our purposes aerobatic training may be counterproductive, producing negative training outcomes, and possibly, as we will see, implanting incorrect technique. The aircraft in question, transport-category aircraft, are not designed nor intended for such flight.

For our purposes, airplane upset is defined as an airplane unintentionally exceeding the parameters normally experienced in line operations or training.

While specific values may vary among airplane types, the following unintentional conditions generally describe an airplane upset:

- Aircraft pitch attitude greater than 25 degrees, nose up.
- Aircraft pitch attitude greater than 10 degrees, nose down.
- Aircraft bank angle greater than 45 degrees.
- Within the above parameters, but flying at airspeeds inappropriate for conditions. (*Airplane Upset Recovery Training Aid, Revision 2*)

Significantly, these flight conditions often occur in combination.

Loss of control, flight upset (LOC-I) is established as the potential event demanding immediate and decisive attention by the aviation industry to avoid further loss of life, vast financial losses, and decline of public confidence. In past years, several developments in technology and improved training have resulted in significant safety improvements for the industry. Generally accepted developments increasing safety have been

- the jet engine.
- improved and operator friendly avionics.
- improved training.
- proactive not reactive safety programs.
- technological improvements.

—weather radar
—TCAS
—TAWS

The emergence of technology as the leading contributor to these results is obvious. CFIT reigned for years as the No. 1 cause of hull losses and loss of life. The industry has responded in a variety of ways, including increased training, at least in emphasis, and regulatory agencies have issued directives and regulations to companies and pilots regarding the seriousness of the matter. Such results produced some mitigation of the problem, but CFIT did not cease to be the major cause of accidents and loss of life until the advent of TAWS, and its mandatory installation and use.

Technology offers little assistance with the challenges inherent in flight upset. Technology, especially autoflight, has not reached the point at which it can react and control flight actions at or beyond the parameters of LOC-I. In fact, in an era in which regulators encourage crews to utilize auto flight and other sophisticated flight aids to the maximum degree possible, pilots are facing a situation in which the parameters of flight upset result in the disconnection of those same systems. Faced with such a challenge crewmembers, whose individual flight skills might have atrophied due to reliance on automation, then must deal with an unfamiliar flight situation they have not prepared for. This "shock" or "stun" factor must be understood as part of the solution.

By necessity, flight upset becomes a training question because of the technology-resistant nature of the problem. The solution should demand a practical approach, using already existing training aids, while remaining within the regulatory guidance of the *Upset Recovery Training Aid, Revision 2 (2008).* The need is established by a string of deadly accidents that illustrate the problem.

One psychological barrier should be examined and dispensed with. Belief that "it won't happen here," because it has not happened, is meaningless, Anything less than a professional and active training program is no longer sufficient. Anything less creates an equation of when the inevitable will happen. Training for flight upset should be as much a business model as anything else related to training and safe operations.

No airline or operator expected these accidents to occur with their crews and aircraft, yet they did.

- USAir Fight 427 (Boeing 737), September 1994
- American Airlines Flight 587 (A300), November 2001
- Pinnacle Airlines Flight 3701 (CRJ200), October 2004
- West Caribbean Airways Flight 708 (MD-82), August 2005

These tragedies were selected for brief examination because they illustrate the problem in clear and unambiguous terms. There are others. In fact, recent tragedies, while investigations continue, show signs within regulatory public statements of possible crew control mismanagement and lack of awareness of actual flight conditions without autoflight.

USAir 427

At approximately 19:00 Eastern Daylight Time on Sept. 8, 1994, USAir Flight 427 (ORD–PIT) descended out of control and crashed, killing all aboard outside of Pittsburgh, Pa.

In the executive summary of the final report of this accident, the NTSB states the following:

"The National Transportation Safety Board determines that the probable cause of the USAir Flight 427 accident was a loss of control of the airplane resulting from the movement of the rudder surface to its blowdown limit. The rudder surface most likely deflected in a direction opposite to that commanded by the pilots as a result of a jam of the main rudder power control unit servo valve secondary slide to the servo valve housing offset from its neutral position and overtravel of the primary slide.

"The safety issues in this report focused on Boeing 737 rudder malfunctions, including rudder reversals, the adequacy of the B-737 rudder system design, unusual attitude training for air carrier pilots, and flight data recorder (FDR) parameters." (p. ix)

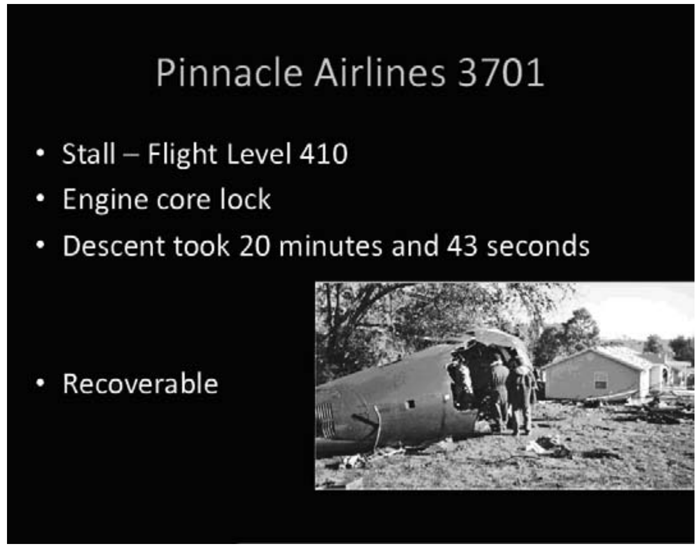
After building thousands of B-737 series aircraft, a significant danger to flight, existing since the original design, was discovered under tragic circumstances. The B-737 had been in service in various versions for years. This cannot be planned for in a standard business plan. However, pilot training mitigation for such nasty surprises can be planned for.

The report includes commentary on the inadequacy of air carrier pilot training to address this type of unexpected flight upset. This resulted in remodeled training for crews flying the B-737, and increased knowledge of more sophisticated aeronautical issues like cross-over speeds. Although this crew had little chance given their previous experience and training, future B-737 crews should fare better. Prominent in the NTSB recommendations were suggestions for more sophisticated training of flight crews so that following such training, an event like USAir Flight 427 could be prevented, but if encountered, be recoverable.

Of interest to operators is the fact that this investigation required more than 4 years to complete and cost the industry more than $1.5 billion in direct and indirect losses.

American Airlines 587

Barely one month following the attacks of Sept. 11, 2001, New York City again faced tragedy from the sky. This time it was not the madness of terrorism, but human error.



At 09:16 Eastern Standard Time, American Airlines Flight 587, an Airbus A300-605 N14053, crashed into a residential area of Belle Harbor, N.Y. Flight 587 was a regularly scheduled flight from JFK to Las Americas International Airport, Danto Domingo, Dominican Republic. Killed were 260 passengers and crew aboard the aircraft, and five people on the ground.

Once fears of terrorism were eliminated, it was evident the aircraft impacted the ground in an ominous fashion. The location of the vertical stabilizer and rudder in Jamaica Bay was proof positive of a structural breakup while in flight.

During the investigation, it became apparent that the aircraft encountered wake turbulence a few minutes after takeoff from a B-747 that departed the same runway immediately before. The pilot flying of the aircraft was the first officer. This encounter is where the trouble started. Wake turbulence around busy traffic areas, mixing aircraft of various sizes and capability, is hardly unknown. In fact, it is frequent.

The executive summary of the NTSB final report on the loss of Flight 587 says the following:

"The National Transportation Safety Board determines that the probable cause of this accident was the inflight separation of the vertical stabilizer as a result of the loads beyond ultimate design that were created by the first officer's unnecessary and excessive rudder pedal inputs. Contributing to these rudder pedal inputs were the characteristics of the Airbus A300-600 rudder system design and *elements of the American Airlines advanced aircraft maneuvering program.*" (p. xi) (authors' italics)

In effect, the report states that the flying pilot excessively loaded the rudder beyond design limits and the system was designed as to allow him to do it.

For our purposes, the Board's concentration on American Airlines advanced aircraft maneuvering program is significant and troubling. It is clear that American Airlines made a strong commitment to address the clear dangers present in loss of control flight upset events. The airline created an aggressive program designed to improve their pilots' awareness and skills. The design of the program was an "in house" training department effort that, at least initially, sought input from manufacturers and regulators. However, as time passed, disagreements on basic aerodynamic theory and technique began to surface. While the program had the very best of intentions, it came under question by the company's operations management. The NTSB final report discussed one significant issue.

"On Feb. 6, 2003, American Airlines provided the Safety Board with a copy of a May 27, 1997, memorandum from the company's managing director of flight operations technical to the company's chief pilot and vice-president of flight. The memorandum stated that the managing director of flight operations technical had 'grave concerns about some flawed aerodynamic theory and flying techniques that have been presented in the AAMP.' The memorandum also stated that it was wrong and 'exceptionally dangerous' to teach pilots to use the rudder as the primary means of roll control in recoveries from high AOAs." (p. 89)

The memorandum continued to request a review of a number of concerns regarding the program, some raised by manufacturer test pilots. In addition to the propensity of the first officer to use excessive rudder, such instruction created a toxic combination that, under demands of the event, stressed the Airbus vertical stabilizer and rudder beyond design limits.

This chain of events illustrates key issues regarding training for inflight upsets. This event brought the entire concept into question in some minds. Carriers developing such programs ceased their development. The fact that American Airlines increased exposure and liability through such a program was not lost on the industry. It also provided additional rationalization for those opposed to such training for various reasons, such as cost, the effort involved, or simple resistance to change. By any estimation, Flight 587 stands as a classic inflight upset event with tragic consequences.

Pinnacle Airlines 3701

At approximately 2215 Central Daylight Time, Pinnacle Airlines Flight 3701, a repositioning flight from Little Rock, Ark., to Minneapolis-St. Paul International Airport in Minnesota, crashed near the Jefferson City, Mo., airport, killing the crewmembers, who were the only souls aboard the aircraft.

The NTSB final report was scathing:

"The National Transportation Safety Board determines that the probable causes of this accident were (1) the pilots' unprofessional behavior, deviation from standard operating procedures, and poor airmanship, which resulted in an inflight emergency from which they were unable to recover, in part because of the pilots' inadequate training; (2) the pilots failure to prepare for an emergency landing in a timely manner, including communicating with air traffic controllers immediately after the emergency about the loss of both engines and the availability of landing sites; and (3) the pilots' improper management of the double engine failure checklist, which allowed the engine cores to stop rotating and resulted in the core lock engine condition. Contributing to this accident were (1) the core lock engine condition, which prevented at least one engine from being restarted, and (2) the airplane flight manuals, which did not communicate to pilots the importance of maintaining a minimum airspeed to keep the engine cores rotating." (p. x)

Professionalism and aircraft knowledge, as well as basic aerodynamics, can be trained. Additionally a well-designed and appropriately taught and monitored training program, containing an inflight upset section, is a useful tool for detecting and, if need be, removing pilots from the system who cannot or will not improve their performance.

The key issue established by Pinnacle 3701 is that regardless of the behavior and the predicament that resulted, the crew could have probably recovered sufficiently to save their lives and the aircraft with knowledge contained in inflight upset training programs.

West Caribbean Airways 708

On Aug. 16, 2005, West Caribbean Airways Flight 708, an MD-82 (HK-4374X) charter flight from Panama to Martinique, descended from cruise altitude in a nose-up flight attitude and crashed near Machiques, Venezuela, killing all 160 persons aboard.

Investigation by the CIAA of Venezuela showed the following:

- Ground scarring indicated impact in a nose-up, slight right roll attitude.
- Wreckage was distributed over a triangle-shaped area approximately 205 meters long by 110 meters at the widest point.
- Both engines exhibited indications of high-speed compressor rotation at the time of ground impact.
- The engine inlets, empennage, and wing leading edges showed no sign of pre-impact damage.
- The horizontal stabilizer was found at about the full airplane nose up position (12 units).

Additionally, the FDR showed that the aircraft had slowed while at cruise altitude before beginning a descent that did not cease until ground impact.

The events discussed here demonstrate the challenge ahead for the industry. Issues include the proper use of technology, preserving, and enhancing non-automated pilot flying skills, corporate commitment, regulatory understanding, and oversight, and significantly "buy in" by the pilot groups.

The post American 587 syndrome is finally waning under the pressure of events and acceptance of the problem. A growing number of operators are developing and implementing pilot training programs, including academic and simulator training. Regulatory agencies are again encouraging airlines to provide education and training in the subject. Airplane manufacturers responded to the challenge by leading an industry team formed to develop the *Airplane Upset Recovery Training Aid, Revision 2 (2008*) with the FAA and other industry experts. This aid provides basic, but useful, guidance and templates for a training program, as well as sample training manual revisions and lessons to begin the process on the correct footing.

As we have seen, airplane upsets happen for a variety of reasons. Some events are more easily prevented than others. Improvement in airplane design and aerodynamic simplicity and equipment reliability continues to be a goal. Automation may have a result counter to intention: we have arrived at the point that when airplane upsets occur, pilots discover degradation in basic flying skills.

In too many recent accidents, pilot inability to recover from an unintended inflight condition (upset or stall) has resulted in the loss of the aircraft and occupants. The number of this accident type can, and should, be reduced. Accident data are clear the greatest risk to the fleet of transport aircraft is loss of control in flight. Through proper training and education, this risk can be reduced. ◆

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Reducing the Risk of Runway Excursions

By Jim Burin, Director of Technical Programs, Flight Safety Foundation, Alexandria, Va., USA

Jim Burin has 41 years of aviation experience and 33 years of experience in the aviation safety field. He is a graduate of Dartmouth College and has a master of science degree in systems analysis from the Naval Post-graduate School. His work in aviation safety includes controlled flight into terrain countermeasures, human factors, safety program organization, accident investigation, operations, administration, education, risk management, and organizational and leadership influences on safety. He is a retired Navy captain, having commanded an attack squadron and a carrier air wing during his 30-year career. Prior to joining the Flight Safety Foundation, he was the director of the School of Aviation Safety in Monterey, Calif., where he was responsible for the safety training of 650 Navy, Marine, Coast Guard, and international safety officers each year. As the director of technical programs, his duties include organizing and overseeing safety committees and managing safety-related conferences and research. He is the chairman of the Foundation's international ALAR (approach and landing accident reduction) effort. He has frequently spoken at safety conferences, seminars, and workshops around the world.

Background

At the request of several international aviation organizations, the Flight Safety Foundation initiated a project entitled Runway Safety Initiative (RSI) to address the challenge of runway safety. This was an international effort with participants representing the full spectrum of stakeholders from the aviation community. The effort initially reviewed the three areas of runway safety: runway incursions, runway confusion, and runway excursions. After a review of current runway safety efforts, specific data on the various aspects of runway safety were obtained. After reviewing the initial data, the RSI Group determined that it would be most effective to focus its efforts on reducing the risk of runway excursions. All data used in this document are taken from the May 2009 report of the RSI (see Reference 1).

A runway excursion was defined as when an aircraft on the runway surface departs the end or the side of the runway surface. Runway excursions can occur on take off or on landing. They consist of two types of events: 1. A veer-off is a runway excursion in which an aircraft departs the side of a runway. 2. An overrun is a runway excursion in which an aircraft departs the end of a runway.

During the 14-year period from 1995-2008, commercial transport aircraft experienced a total of 1,429 accidents involving major or substantial damage (see Table 1). Of those, 431 accidents (30%) were runway related. The specific RSI focus on excursion accidents was driven by the fact that of the 431 runway-related accidents, 417, or 97%, were runway excursions.

The number of runway *excursion* accidents is more than 40 times the number of runway *incursion* accidents, and more than 100 times the number of runway *confusion* accidents (see Table 2). During the past 14 years, there has been an average of almost 30 runway excursion accidents per year for commercial aircraft, while runway incursion and confusion accidents combined have averaged one accident per year.

Aircraft Type	Turbojet		Turboprop	
Damage	Major	Substantial	Major	Substantial
	286	372	528	243
Total	658		771	
1,429 Total Accidents				
Western- and Eastern-built Turbojet and Turboprop Aircraft				

Table 1. Total Commercial Transport Accidents, 1995-2008

Accident Type	Number of Accidents	Average Annual Rate	% of Total Accidents
Incursion	10	0.7	0.6%
Confusion	4	0.3	0.3%
Excursion	417	29.8	29.0%

Table 2. Runway-Related Accidents for Commercial Turbojet and Turboprop Aircraft

Figure 1 shows that the largest portion of runway-related accidents is, by far, excursion accidents.

Forty-one of the 431 runway accidents involved fatalities. Excursion accidents accounted for 34 of those 41 fatal accidents, or 83% of all fatal runway-related accidents. In general, the likelihood of fatalities in a runway-related accident is greater in incursion and confusion accidents. However, the much greater number of runway excursion accidents results in a substantially greater number of fatal excursion accidents (see Figure 2).

Only a small percentage of runway excursion accidents are fatal. However, since the overall number of runway excursion accidents is so high, that small percentage accounts for a large number of fatalities. During the 14-year period, 712 people died in runway excursion accidents, while runway incursions accounted for 129 fatalities and runway confusion accidents accounted for 132 fatalities.

Discussion

Who is responsible to address the challenge of runway excursions? The

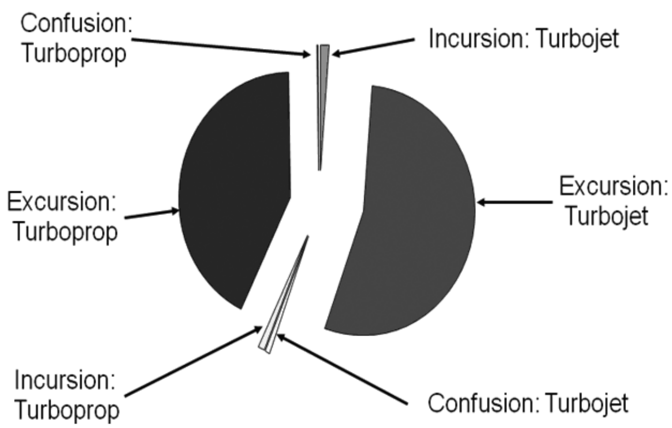

Figure 1. Proportions of runway-related accidents for commercial turbojet and turboprop aircraft.

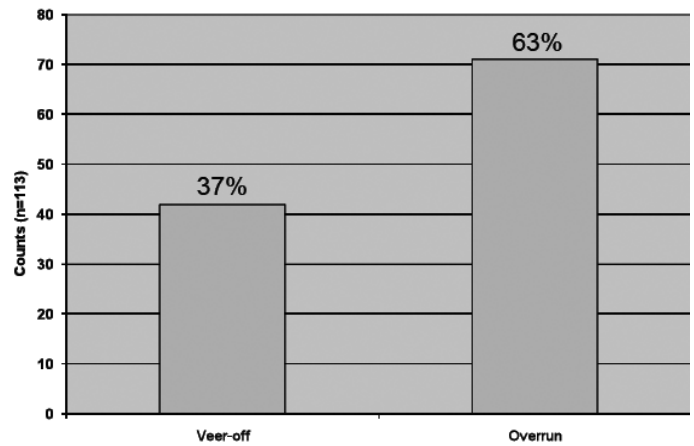

Figure 4. Takeoff excursions, by type.

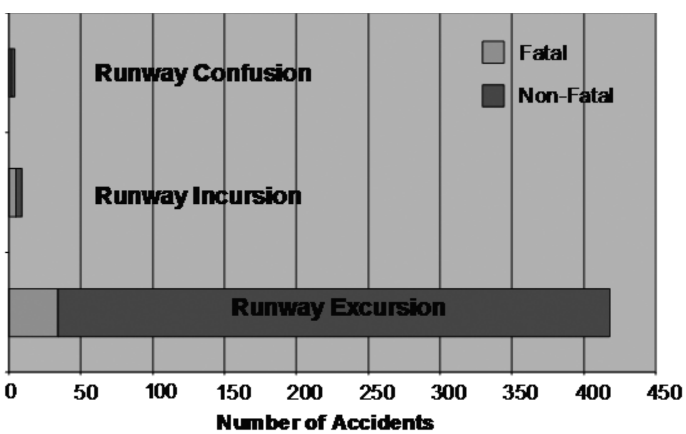

Figure 2. Proportions of fatal and non-fatal runway accidents.

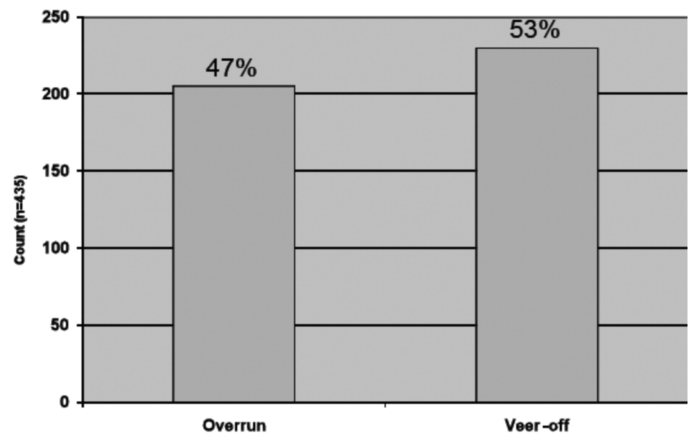

Figure 5. Landing excursions, by type.

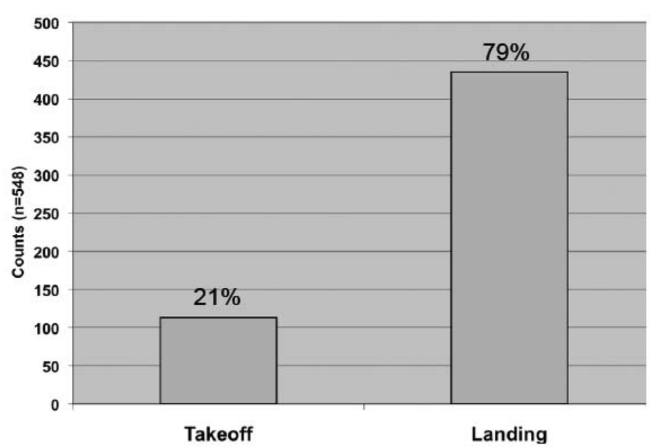

Figure 3. Runway excursions, by type.

answer is everyone aircraft manufacturers, operators (both aircrews and management), airports, air traffic control, and regulators.

The manufacturers do a great job of providing the operators with safe and reliable aircraft. They also provide data and procedures the crews will need in most day-to-day operations. However, without good data on how the aircraft will perform under all runway conditions, some landings have the potential of becoming physics experiments. Operators must have and monitor stabilized approach criteria, since the data clearly show that unstabilized approaches are a primary risk factor in landing excursions. Operators also need to have a true no-fault go-around policy because the leading risk factor in landing excursions is failure to go around when warranted.

Airports have many issues to address in the runway excursion area. These include issues such as airport design, lighting, approach aids, runway design (e.g., crowned, grooved, porous), markings and signage, runway cleaning and clearing, runway condition measurement, runway end safety areas, and aircraft rescue and firefighting.

Air traffic management/air traffic control has two primary roles in reducing the risk of runway excursions: first, to provide air traffic services that give flight crews the opportunity to fly a stabilized approach. Second, to ensure that aircrews are given the best available information on environmental and runway conditions in a timely manner.

Finally, the regulator needs to encourage and provide more approaches with vertical guidance, since these assist in enabling stabilized approaches. They also need to be sure that aircrews are provided with the best possible information from the manufacturers for operations under all conditions. Regulators should also require some universal system for measuring and reporting runway conditions.

Data

An in-depth data study was conducted of all runway excursion accidents from 1995-March 2008 to investigate the causes of runway excursion accidents and to identify the high-risk areas. Following are some of the basic data from the study.

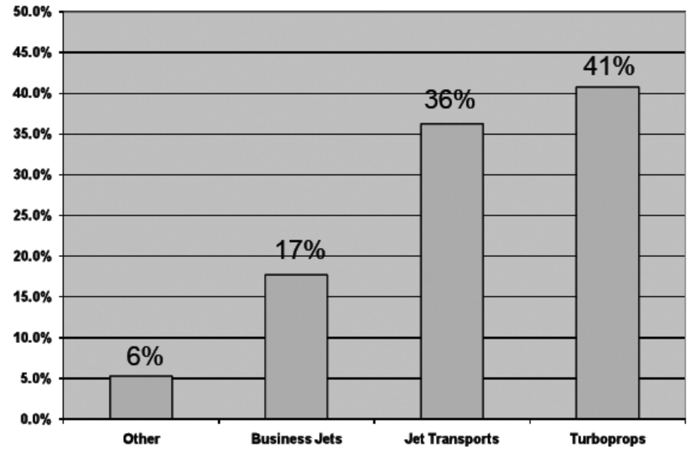

Figure 6. Takeoff excursions, by fleet composition.

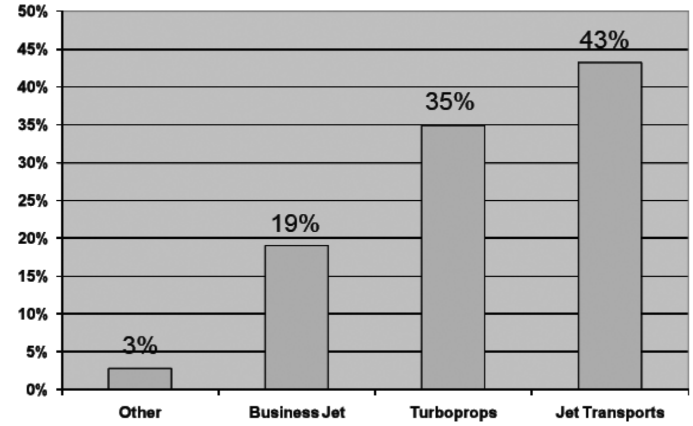

Figure 7. Landing excursions, by fleet composition.

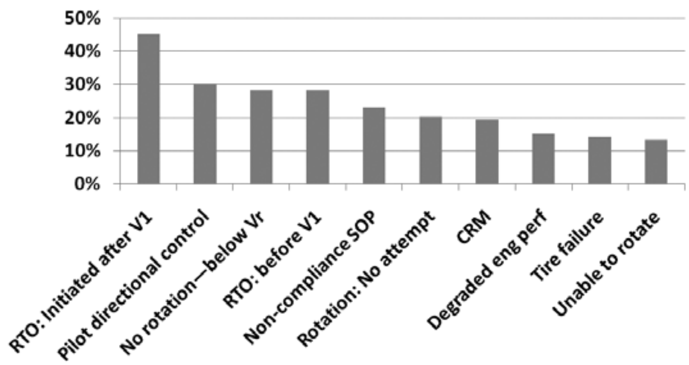

Figure 8. Takeoff excursion risk factors.

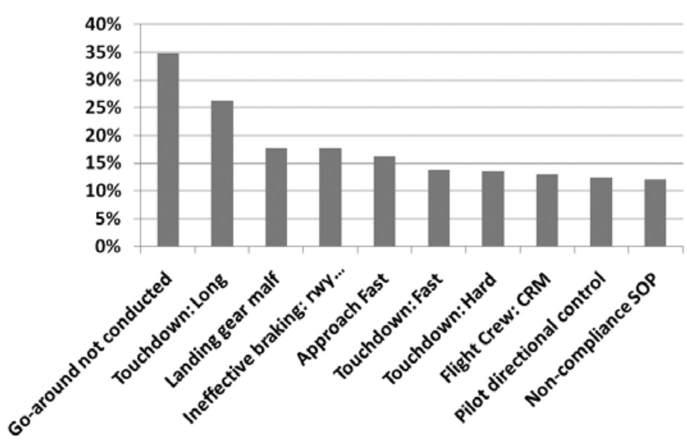

Figure 9. Landing excursion top risk factors.

Landing excursions outnumber takeoff excursions approximately 4 to 1 (see Figure 3).

Almost two-thirds of the takeoff excursions are overruns (see Figure 4).

Landing excursion overruns and veer-offs occur at nearly the same rate (see Figure 5).

Among aircraft fleet types, turboprops are involved in the largest percentage of takeoff excursions, followed closely by jet transports (see Figure 6).

For landing excursions, the proportions between jet transports and turboprops were approximately reversed—jets were involved in more excursions than turboprops (see Figure 7).

The data were analyzed to identify the most common risk factors, both in takeoff excursions (see Figure 8) and landing excursions (see Figure 9). More than one risk factor could be assigned to an accident.

The most common risk factor in takeoff excursions was a rejected takeoff (RTO) initiated at a speed greater than V_1. Loss of pilot directional control was the next most common, followed by rejecting the takeoff before V_1 is reached. This is of concern since aborting prior to V_1 should result in a successful RTO.

For landing excursions, the top risk factors were go-around not conducted, touchdown long, landing gear malfunction, and ineffective braking (e.g., hydroplaning, contaminated runway). Three of the top 5 risk factors deal with elements of a stabilized approach.

Risk Factor Interactions

The risk of a runway excursion increases when more than one risk factor is present. Multiple risk factors create a synergistic effect (i.e., *two* risk factors *more than double* the risk). Risk factor interactions present the possibility of many associations between various contributing factors, but determining whether any pair of associated factors has a causal connection would require more detailed study and analysis.

As an example, risk factor interactions for landing overruns show strong associations between "go-around not conducted" and other factors such as "unstabilized approaches," "long/fast landings," "runway contamination," and "hard/bounced landings." Logically, these factors may have a causal connection to each other that significantly increases the probability of a runway excursion accident. In looking at some risk factor interactions for takeoff excursions, the risk factor interactions suggest that there might be interesting associations between engine power loss and aborts initiated above V_1, as well as an association between these high-speed aborts and the presence of runway contaminants.

Summary

The RSI team fully supports the many outstanding activities being conducted around the world by organizations like the FAA, ICAO, and Eurocontrol that have been responsible for the low number of runway incursion accidents. The specific goal of the RSI team was to provide data that highlight the high-risk areas of runway excursions and to provide interventions and mitigations that can reduce those risks. The RSI effort brought together multiple disciplines that included aircraft manufacturers, operators, management, pilots, regulators, researchers, airports, and air traffic management organizations. It used the expertise and experience of all the stakeholders to address the challenge of runway excursions.

Conclusions and recommendations

1. A mishandled rejected takeoff (RTO) increases the risk of takeoff runway excursion

- Operators should emphasize and train for proper execution of the RTO decision.
- Training should emphasize recognition of takeoff rejection issues:
—Sudden loss or degradation of thrust,
—Tire and other mechanical failures, and
—Flap and spoiler configuration issues.
- Training should emphasize directional control during deceleration.
- CRM and adherence to SOPs are essential in time-critical situations such as RTOs.

2. Takeoff performance calculation errors increase the risk of a takeoff runway excursion

- Operators should have a process to ensure a proper weight and balance, including error detection.
- Operators should have a process to ensure accurate takeoff performance data.

3. Unstable approaches increase the risk of landing runway excursions

- Operators should define, publish, and train the elements of a stabilized approach.
- Flight crews should recognize that fast and high on approach, high at threshold, and fast, long, and hard touchdowns are major factors leading to landing excursions.
- ATC/ATM personnel should assist aircrews in meeting stabilized approach criteria.

4. Failure to recognize the need for and to execute a go-around is a major contributor to runway excursion accidents

- Operator policy should dictate a go-around if an approach does not meet the stabilized approach criteria.
- Operators should implement and support no-fault go-around policies.
- Training should reinforce these policies.

5. Contaminated runways increase the risk of runway excursions

- Flight crews should be given accurate, useful, and timely runway condition information.
- A universal, easy-to-use method of runway condition reporting should be developed to reduce the risk of runway excursions.
- Manufacturers should provide appropriate operational and performance information to operators that accounts for the spectrum of runway conditions they might experience.

6. Thrust reverser issues increase the risk of runway excursions

- Flight crews should be prepared for mechanical malfunctions and asymmetric deployment.
- Flight crew application of reverse thrust is most effective at high speeds.

7. Combinations of risk factors (such as abnormal winds plus contaminated runways or unstable approaches plus thrust reverser issues) synergistically increase the risk of runway excursions

- Flight crews should use a runway excursion risk awareness tool for each landing to increase their awareness of the risks that may lead to a runway excursion.

8. Establishing and adhering to standard operating procedures (SOPs) will enhance flight crew decision-making and reduce the risk of runway excursions

- Management and flight crews should mutually develop SOPs.
- SOPs should be regularly reviewed and updated by a management and flight crew team.

9. The survivability of a runway excursion depends on the energy of the aircraft as it leaves the runway surface and the terrain and any obstacles it will encounter prior to coming to a stop

- All areas surrounding the runway should conform to ICAO Annex 14 specifications.
- All runway ends should have a certified runway end safety area (RESA) as required by ICAO Annex 14 or appropriate substitute (e.g., an arrestor bed).
- Aircraft rescue and firefighting (ARFF) personnel should be trained and available at all times during flight operations.

10. Universal standards related to the runway and conditions, and comprehensive performance data related to aircraft stopping characteristics, help reduce the risk of runway excursions

- Regulators should develop global, uniform standards for runway condition measuring and reporting, and aircraft performance data. ◆

References

1. Flight Safety Foundation (May 2009). Reducing the Risk of Runway Excursions, Report of the Runway Safety Initiative.

Developing Investigations to Enhance Safety Worldwide

By Marcus Costa, Accident Investigation and Prevention Section, ICAO

Marcus A. Costa has been chief of the Accident Investigation and Prevention Section at ICAO headquarters since November 2004. He has been an air safety investigator since 1981. From 1985 to 2004, he was a staff and faculty member with CENIPA/Brazil. He served as an accredited representative of Brazil to accidents in the United States in 1995 and 1996. In 1999, Costa was the Brazilian delegate to the ICAO AIG Divisional Meeting. He served as chief of CENIPA in 2002 and 2003 and in 2008 served as secretary of the AIG Divisional Meeting. A native of Brazil, he served with the Brazilian Air Force, retiring with the rank of colonel. He completed the U.S. Air Force Flight Safety Officer's Course in 1985 and received a master's degree in aviation safety from Central Missouri State University in the United States in 1994.

Introduction

Thee Accident Investigation and Prevention (AIG) Divisional Meeting 2008 (AIG/08) took place at the headquarters of the International Civil Aviation Organization (ICAO) in Montréal from Oct. 13-18, 2008, with the participation of some 225 participants from 75 States and 12 international organizations.

The theme of the meeting was "Developing Investigations to Enhance Safety Worldwide." The meeting addressed a number of important provisions in Annex 13—*Aircraft Accident and Incident Investigation*—with a view to further improving and amplifying the scope of investigations in a cost-effective environment.

Outcomes of the meeting

Participants at the eighth AIG Divisional Meeting put forth 24 proposals to amend provisions in Annex 13 and another 23 recommendations of general nature aimed at improving aircraft accident and incident investigation and prevention for the enhancement of aviation safety worldwide.

Among other issues, the meeting discussed the future of accident and incident investigations, with the goal to assist some States through the development of regional investigation bodies.

Reflected in the meeting's outcomes was the recognition that innovative approaches to accident and incident investigation are needed given the current realities of evolving technologies and resource constraints. Some of the important recommendations that were agreed upon include the following:

a) focusing investigations on those accidents in which safety lessons are expected to be learned.

b) stronger emphasis on the investigation of serious incidents which will provide additional safety data.

c) development of guidance material on regional cooperation in accident and incident investigations to assist those States lacking the necessary means.

d) public availability of final accident reports in the interest of accident prevention.

e) improved safety information sharing through the use of common safety taxonomies.

f) reporting of accidents involving unmanned aircraft systems (UAS) and very light jets.

g) endorsement of a framework model memorandum of understanding for cooperation between States in accident and incident investigations.

h) improved guidance on the coordination of Annex 13 investigations and judicial processes.

i) promotion of enhanced monitoring and resolution of safety recommendations.

j) assessment of Annex 13-related shortcomings identified by ICAO's Universal Safety Oversight Audit Program (USOAP).

Protection of safety information

With regard to the protection of certain accident and incident records, it is worth noting that the meeting participants unanimously agreed to recommend that ICAO undertake a study aimed at reviewing and facilitating the implementation of Paragraph 5.12 and Attachment E to Annex 13 with the assistance of an appropriate group of experts. In this connection, it is further noted that a proposal was made by the meeting participants to expand Paragraph 5.12 to address the protection of cockpit airborne image recordings.

Recommendations for amendments to Annex 13

The 24 recommendations for amendments to Annex 13 can be found in the report of the meeting (ICAO Doc. 9914). In March 2009, the Air Navigation Commission of ICAO reviewed the recommendations and agreed to seek the comments of States and international organizations. Following receipt of comments, the Commission will conduct a final review of the proposals, which will then be presented to the ICAO Council for adoption of amendments to Annex 13 in March 2010.

Recommendations on matters other than amendments to Annex 13

The 23 recommendations other than amendments to Annex 13 considered the following: 2 recommendations addressed general

ICAO policies, 11 dealt with AIG documentation and training, 5 related to safety data, 2 concerned safety recommendations, 2 related to flight recorders, and 1 covered AIG-related findings during USOAP.

In June 2009, the Council noted the actions taken by the Commission on 21 recommendations and took action on the other 2 recommendations.

Those recommendations are presented in a supplement to the report of the meeting and were distributed to States and international organizations in July 2009.

Conclusion

The meeting fully achieved its objective, and it was widely recognized that it also provided a rare opportunity for members of accident investigation authorities to network and exchange ideas, paving the way for additional cooperation among States.

Further information concerning AIG/08, including reports on all agenda items, is available on the website www.icao.int/aigdiv08. ◆

A Comparison Study of GPS Data And CDR Radar Data Using a Fully Instrumented Flight Test

By Ryan M. Graue, Aeronautical Engineer, AvSafe, LLC, Chesterfield, Mo.; Jean H. Slane, Senior Consultant, Engineering Systems Inc., Colorado Springs, Colo.; Dr. Robert C. Winn, Principal Engineer, Engineering Systems Inc., Colorado Springs, Colo.; W. Jeffrey Edwards, President, AvSafe, LLC, Chesterfield, Mo.; and Krista B. Kumley, Consultant, Engineering Systems Inc., Colorado Springs, Colo.

***Ryan Graue** is an aeronautical engineer at AvSafe, LLC. His work involves determining aircraft flight paths and flight parameters using recorded radar data, creating simulations of aircraft accident scenarios, planning flight tests, and analyzing flight test data. He also has experience in the Aviation Systems Group at Garmin International where he performed development work on the G1000 and G900X integrated avionics suites. He was responsible for leading a program to update the G900X from a two-display unit to a three-display unit with dual sensors.*

Photo not available

***Jean Slane** is an aeronautical engineer specializing in modeling and simulation software in the Colorado Springs office of Engineering Systems Inc. (ESI). Her consulting work has included the design and development of mathematical models for a variety of commercial, general aviation, and military aircraft simulators. Slane served as an officer in the USAF with duties including lead flight control engineer for the Space Shuttle project at Vandenberg Air Force Base. While a project engineer for Honeywell Defense Avionics System Division, she participated in the control system software design for the C-17 aircraft.*

Photo not available

***Dr. Robert Winn** joined Engineering Systems Inc. (ESI) in 1994 and is now a principal and the director of the Colorado operations for ESI in Colorado Springs, Colo. Dr. Winn served as a pilot and engineer in the USAF for more than 22 years and spent more than 15 years as a university professor teaching aeronautical and mechanical engineering at the USAF Academy and Colorado Technical University. He is a Fellow of the American Institute of Aeronautics and Astronautics. Dr. Winn has published more than 70 technical papers, technical reports, and articles.*

Photo not available

***William Jeffrey Edwards** served in the United States Navy flying A-6 Intruders aboard the USS* John F. Kennedy *and USS* Forrestal. *He later served as an aircraft accident investigator with the U.S. Naval Safety Center where he investigated Navy and Marine Corps aircraft accidents around the world. Following retirement from the Navy in 1993, he served as an aircraft accident investigator for McDonnell Douglas Aerospace and Boeing, investigating civil and military aviation mishaps. In 1997, he founded AvSafe, LLC, an aviation safety consulting company that provides consulting services to the insurance and legal industries. Edwards has consulted on more than 350 aircraft accident cases throughout his career.*

Photo not available

***Krista Kumley** joined Engineering Systems Inc. (ESI) in 2007. She has a master of science degree in forensic science and is currently working on a master of science degree in mechanical engineering with a specialization in dynamics and controls.*

I. INTRODUCTION

Aircraft accident investigators often use radar data provided by the Federal Aviation Administration (FAA) to aid in analyzing and reconstructing accident scenarios. However, simply analyzing the raw radar returns usually yields unsatisfactory results due to noise and resolution limits in the recorded data. In order to obtain results that accurately reflect the flight path and give an accurate time history of the flight parameters of the accident flight, accident investigators must smooth the data to reduce the noise. In recent years, experts in flight path reconstruction have developed several different smoothing and analysis techniques to accomplish this goal (see References 1-6).

Unfortunately, most general aviation aircraft are not equipped with flight data recorders. As a result, when an accident involving a general aviation aircraft occurs, recorded radar data are often the only evidence investigators can use to determine the accident flight path and gain an understanding of the manner in which other parameters such as airspeed, altitude, bank angle, and heading changed throughout the flight. Experts analyzing data from the same accident flight may arrive at different conclusions regarding the nature of the flight due to differences in the smoothing and analysis techniques they choose. Since no other evidence may be available, these differing conclusions may lead the experts to have differing opinions regarding flight paths and flight dynamics. The goal of this research is to try to eliminate some of the discrepancies that result from differing interpretations of radar data.

Radar data analysis involves two major aspects in the context of aircraft accident investigation: flight path reconstruction and flight parameter reconstruction. Flight path reconstruction is important because it tells the investigator where the aircraft was located at specific times throughout the flight. Flight parameter reconstruction

TARGET REPORTS

STIME	SN	RANGE NM	ACP	DEG	QUA	BEACON	ALT	COR ALT	SYSTEM X NM	SYSTEM Y NM	PS	STR	SC	RSM	RL	BHC	AQ	TQ	TC	TE	TYP	SYS	RSB RNK
20:41:10.590	24	31.09	2796	246	7	1200-3	023-3	024	51.20	81.77	0	S				20	7				RB	0	1
		12.59	2795	246	3				68.33	89.05	0						3	0	3	3	RT	0	1
		12.61	2830	249	7	1200-3	011-3	012	67.95	89.64	0	S				20	7				RB	0	1
20:41:10.740	25	38.77	2893	254	7	1200-3	069-3	070	42.31	84.22	0	S				20	7				BT	0	1
		38.78	2884	253	3				42.45	83.70	0						3	0	3	3	RT	0	1
		19.42	2901	255	5	1200-3	025-3	026	60.95	89.31	0	S				20	5				RB	0	1
		13.33	2942	259	6	0520-3	100-3	101	66.77	91.61	0	S				28	6				RB	0	1
		34.44	2933	258	7	1200-3	073-3	074	46.03	87.38	0	S				20	7				RB	0	1
20:41:10.890	26	43.14	3031	266	4	1200-3	027-3	028	36.70	92.13	0	S				20	4				RB	0	1
		47.22	3086	271	7	4655-3	180-3	180	32.72	95.94	0	S				28	7				RB	0	1
		8.19	3084	271	7	0235-3	014-3	015	71.61	94.30	0	S	ID			20	7				RB	0	1
		43.72	3144	276	7	1273-3	850-3	000	36.47	99.67	0	S		2		28	7				BT	0	1
		41.81	3126	275	4	3273-3	320-3	320	38.53	98.25	0	S				28	4				RB	0	1
		11.56	3155	277	4				68.47	95.67	0						4	1	4	1	RT	0	1
		11.52	3147	277	7	1200-3	020-3	021	68.39	95.53	0	S				20	7				BT	0	1

Figure 1. Sample from FAA CDR data file showing test flight radar data.

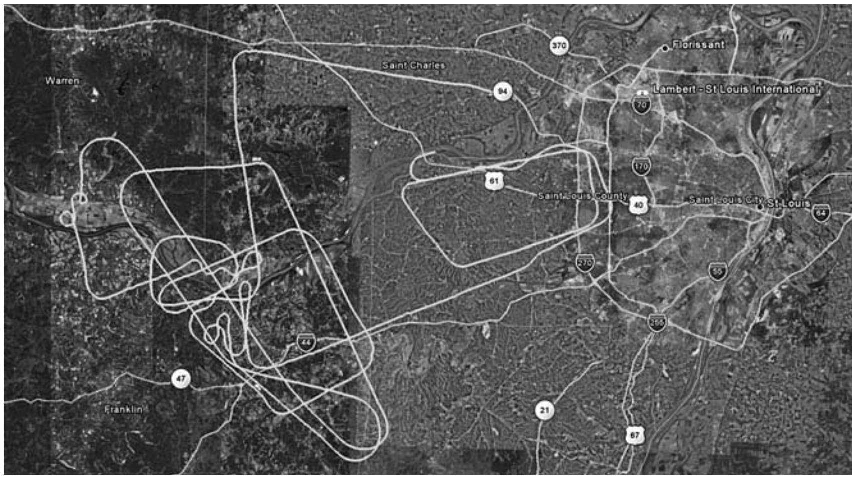

Figure 2. Flight test ground track.

is also critical because it gives the investigator an understanding of how the aircraft performed in order to generate the radar recorded accident flight. As both of these aspects are key components of aircraft accident investigation, the flight test data analysis will include comparisons of the flight paths and the flight parameters.

II. EXPERIMENTAL SETUP

In order to minimize the discrepancies in analyzing and interpreting radar data, an experiment was devised to compare different smoothing techniques against a "true" indication of all flight data. To accomplish this goal, a fully instrumented flight test was flown with multiple flight data recorders on board. A file containing FAA continuous data recording (CDR) radar return information was obtained for the same flight. Flight data recorder information served as the experimental control, while different smoothing levels and calculation methods were applied to the radar data for comparison with the flight data recorder information.

To model various segments of accident flight scenarios, the following maneuvers were flown: straight and level, climb, descent, S-turns, steep turns, chandelles, instrument approach, and autopilot turn. The recorded radar data from each maneuver were processed using four levels of smoothing and two calculation methods. The flight parameters were calculated for each combination of smoothing level and calculation method. The flight parameters compared in this study were ground speed, true airspeed, bank angle, load factor, magnetic heading, and turn rate.

III. FLIGHT TEST

A. Aircraft and data recording equipment

The aircraft utilized for this testing was a Lancair IV-P. This particular aircraft was chosen for its ability to perform all the necessary flight maneuvers and fly at a wide range of airspeeds. Onboard equipment included an Appareo Systems GAU 1000A flight data recorder with WAAS-enabled GPS, a Chelton Flight Systems Sport, and a WAAS-enabled Garmin GPSMAP 396.

B. Radar facility and description of radar data

Radar data were gathered from the St. Louis/Lambert (KSTL) Terminal Radar Approach Control (TRACON) ASR-9 antenna. Information obtained from the radar data file included the times of the radar returns, range, and azimuth angle relative to the antenna and Mode C (pressure) altitude. Highlighted in Figure 1 is a test data sample from the CDR data file provided by the FAA.

C. Flight path

The flight path for the entire flight test is shown in Figure 2. The flight lasted approximately 2 hours and was flown in the area west of St. Louis in east central Missouri. More than 1,300 radar returns were obtained from the flight.

IV. ANALYSIS

A. Wind and temperature at altitude

To perform a flight parameter analysis, regardless of the smoothing level or calculation method, the winds and temperature at altitude are needed. The data acquisition systems on board the test aircraft were capable of calculating and displaying the winds being encountered; however, they could not be automatically recorded. In addition, it is very rare that an accident reconstructionist will know the true wind and temperature profile throughout a flight. Without the assistance of an experienced meteorologist, the best approach is to use weather data recorded by the National Oceanic and Atmospheric Administration. This agency records wind speed and direction, temperature, and several other parameters at locations across the country at 0 UTC and 1200 UTC every day. The stations are typically located approximately 200 nautical miles apart. Because of the geographic and temporal separation of the recorded weather data, it is likely that the data will only give an approximation of the actual weather at altitude on the day of an accident. However, this is the best approximation available in most accident reconstructions.

The flight test occurred in an area nearly equidistant from the Lincoln, Ill., and Springfield, Mo., stations approximately w hours before the 0 UTC weather recording. For the flight parameter analysis, the average winds and temperatures between these two stations were used.

B. Smoothing data

A key step in analyzing the flight test data was to smooth the radar data and generate sets of position matrices for several different levels of smoothing. The following levels of smoothing were used: no smoothing, 5 point least squares moving quadratic, 9 point least squares moving quadratic, and 13 point least squares moving quadratic.

To apply the least squares moving quadratic technique, the raw

	Average Position Error (nautical miles)							
	Straight and Level	Climb	Descent	S-Turns	Steep Turns	Chandelles	Instrument Approach	Autopilot Turn
No Smoothing	0.04567	0.08439	0.01702	0.09036	0.09301	0.05354	0.03075	0.02487
5 Pt. LS	0.04497	0.08404	0.01396	0.08965	0.09405	0.05374	0.03044	0.02461
9 Pt. LS	0.04449	0.08346	0.01232	0.09129	0.11015	0.06385	0.03042	0.02425
13 Pt. LS	0.04482	0.08344	0.01178	0.11560	0.14226	0.09995	0.03082	0.02450

Table 1. Average Position Error for All Maneuvers and Smoothing Levels

radar data points were converted to a position matrix in a Cartesian coordinate system, using nautical miles east of the radar antenna for the "x" coordinates and nautical miles north of the radar antenna for the "y" coordinates. The altitude was used as the "z" coordinate as recorded. In this smoothing technique, a least squares quadratic function was fit using a specified number of points for each set of coordinates independently with time as the independent variable. As the number of points used to determine the quadratic function was increased, the amount of smoothing applied to the radar data increased.

It should be noted that many additional data smoothing techniques can be found in the literature (digital filter, weighted moving average, spline, etc.). For this study, only the least squares moving quadratic technique was used.

C. Flight path comparison

The flight paths that were recorded by the onboard data acquisition equipment did not always exactly match the radar returns that were recorded by the FAA radar facility. In order to quantify the differences in the flight paths, the straight line distance was calculated between each smoothed radar return location and the position information from the flight data recorder at the same moment in time. The distances between these points were calculated, yielding a set of position errors. The average position error was calculated for each of the eight flight maneuvers using both smoothed and unsmoothed data. An assessment of the error between the onboard recorded data and the smoothed flight path points is shown in Table 1. The smoothing levels that gave the closest agreement are shaded.

The results shown in Table 2 lead to the following conclusions:

- For straight flight (straight and level, climb, descent, and instrument approach), high levels of smoothing generally resulted in the best agreement with the onboard recorded position data.
- For maneuvering flight (S-turns, steep turns, chandelles, and autopilot turn), little or no smoothing generally gave the closest agreement.

D. Flight parameter comparison

To compare the flight parameters, each parameter was calculated using the smoothed and unsmoothed position matrices and compared to the logged flight data. Values of ground speed, bank angle, load factor, and turn rate were compared to data from the Appareo unit, while true airspeed and magnetic heading values were compared to data from the Chelton unit.

The process of calculating the flight parameters is based on the seminal work done for NASA by Bach and Wingrove (see Reference 1). In their work, the path between smoothed points is described by a straight line—a rectilinear approach. Recognizing that an airplane cannot abruptly change direction at a point, a curvilinear approach was developed by Slane and Winn (see Reference 5). In the curvilinear approach, a circular flight path is defined by three consecutive smoothed points. In both methods, the path between the points does not have to be in the horizontal plane.

To determine which smoothing level and calculation method yielded the most accurate flight parameter reconstruction, the flight parameters that were logged on the flight data recorders were interpolated to the same times as the radar returns. Next, the errors between these logged flight parameter values and the calculated flight parameter values were determined for each maneuver, yielding a set of error values. The error sets were compared by taking the mean of the absolute values of the errors. The results shown in Table 2 below give the mean absolute error for all flight parameters for each maneuver. The errors for each maneuver are shown in the columns of the table. The rows show the method (rectilinear or curvilinear) and smoothing level used to calculate the flight parameters. The shaded values show the calculation method and smoothing levels that had relatively low errors for that parameter and maneuver.

These results lead to several observations. As a general rule, nearly straight flight is best analyzed using high levels of smoothing, while maneuvering flight is best analyzed using low levels of smoothing. This is consistent with the earlier finding regarding the smoothing

		Flight Parameter Mean Absolute Error Chart – Straight and Level					
		Ground Speed (knots)	True Airspeed (knots)	Mag. Heading (deg)	Load Factor (G's)	Bank Angle (deg)	Turn Rate (deg/sec)
Rectilinear	No Smoothing	3.14032	6.43505	2.89963	0.06573	10.7544	4.43669
	5 Pt. LS	1.47633	5.89922	2.47008	0.01543	3.07608	0.87393
	9 Pt. LS	0.56079	5.63933	2.49069	0.01345	1.5148	0.19267
	13 Pt. LS	0.51661	5.56111	2.50228	0.01265	1.52783	0.18609
Curvilinear	No Smoothing	3.61626	7.06779	2.91429	0.06655	10.81129	4.46139
	5 Pt. LS	2.22971	6.14135	2.60594	0.01897	3.07608	0.87393
	9 Pt. LS	0.66115	5.89062	2.55741	0.01637	1.5148	0.19267
	13 Pt. LS	0.63972	5.77667	2.41279	0.01377	1.52783	0.18609

		Flight Parameter Mean Absolute Error Chart – Climb					
		Ground Speed (knots)	True Airspeed (knots)	Mag. Heading (deg)	Load Factor (G's)	Bank Angle (deg)	Turn Rate (deg/sec)
Rectilinear	No Smoothing	8.78351	14.47155	2.01247	0.04498	6.908	2.90952
	5 Pt. LS	3.01846	13.82816	1.88325	0.02039	2.97634	0.4625
	9 Pt. LS	1.4916	14.43648	1.92892	0.01714	2.84726	0.26242
	13 Pt. LS	0.77608	14.72472	1.97077	0.01659	2.90662	0.25669
Curvilinear	No Smoothing	8.59151	16.2445	2.09157	0.049	7.07848	2.98356
	5 Pt. LS	5.11043	14.24011	1.83929	0.02723	2.97634	0.4625
	9 Pt. LS	2.75779	14.43817	1.78677	0.02197	2.84726	0.26242
	13 Pt. LS	2.12358	14.66489	1.86047	0.01858	2.90662	0.25669

		Flight Parameter Mean Absolute Error Chart – Descent					
		Ground Speed (knots)	True Airspeed (knots)	Mag. Heading (deg)	Load Factor (G's)	Bank Angle (deg)	Turn Rate (deg/sec)
Rectilinear	No Smoothing	8.49003	9.41383	0.91081	0.08853	4.86701	2.002
	5 Pt. LS	3.38084	5.75811	0.81473	0.02022	1.2504	0.32654
	9 Pt. LS	1.36285	4.57978	0.90105	0.01137	1.15476	0.21001
	13 Pt. LS	0.77286	4.51576	1.0091	0.01164	1.23403	0.21218
Curvilinear	No Smoothing	10.48268	11.77982	0.90717	0.09239	4.86701	2.002
	5 Pt. LS	5.57052	7.44293	0.82852	0.02748	1.2504	0.32654
	9 Pt. LS	3.00942	5.45565	0.8194	0.01837	1.15476	0.21001
	13 Pt. LS	1.53467	4.82965	0.89659	0.01428	1.23403	0.21218

		Flight Parameter Mean Absolute Error Chart – S-Turns					
		Ground Speed (knots)	True Airspeed (knots)	Mag. Heading (deg)	Load Factor (G's)	Bank Angle (deg)	Turn Rate (deg/sec)
Rectilinear	No Smoothing	9.93786	7.83506	15.80732	0.12661	10.44773	4.66116
	5 Pt. LS	4.81819	7.48077	15.38779	0.06315	4.90672	1.7011
	9 Pt. LS	8.62069	17.1727	17.30538	0.09935	9.16853	1.68231
	13 Pt. LS	19.47244	26.26549	22.20329	0.13071	15.38407	2.04681
Curvilinear	No Smoothing	14.03317	7.72776	15.85395	0.13412	10.77955	4.78447
	5 Pt. LS	11.88271	6.36624	15.63138	0.07155	5.0061	2.02139
	9 Pt. LS	7.45995	7.96117	15.65827	0.08261	6.97108	2.09977
	13 Pt. LS	6.37006	14.11618	11.99694	0.10628	13.18262	2.59601

Table 2. Flight Parameter Mean Absolute Error Results

levels that resulted in the best flight paths. Here are some additional findings:

- In almost every case, the calculation of true airspeed resulted in significantly larger error than the calculation of ground speed. To calculate true airspeed from ground speed, the winds at altitude were needed. Errors in the calculation of true airspeed were likely higher because of errors in the wind profile at altitude.
- For straight and level, climb, and descent, the best results were obtained with 9 and 13 point smoothing for both rectilinear and curvilinear analyses. For the instrument approach, the calculation of ground speed using rectilinear analysis with 13 point smoothing was slightly more in error.
- For S-turns, steep turns, chandelles, and autopilot turn, low levels of smoothing are preferred; however, in most cases, 5 point smoothing yielded better results than no smoothing. Using high levels of smoothing generally results in the smoothed points being placed toward the inside of each turn. This causes the calculated distance travelled to be less than actual; therefore, the calculated ground speed is lower than actual.
- For S-turns, steep turns, chandelles, and autopilot turn, the errors in heading are quite large; however, this is expected when considering that the heading changed very rapidly during these maneuvers. In nearly straight flight where heading could be an important issue, the calculated headings are quite accurate.
- In general, for S-turns, steep turns, chandelles, and autopilot turn, curvilinear analysis is superior to rectilinear. This is due to the fact that the curvilinear analysis considers the airplane flying in a curved path between points, creating a much more realistic reconstruction than the airplane flying a straight path and turning abruptly at each point.

To determine bank angle for steep turns, the best approach was determined to be 5 point smoothing with either the rectilinear or curvilinear approach, but even so, the calculated bank angle was still rather high. The explanation for this finding can be found by looking at the radar returns that were missed by the radar facility. In Figure 3, the radar data and the ground track of the airplane are shown. Notice that in the second (more northerly) of the two steep turns, several radar returns are missing. These missing returns are due to the airplane's transponder antenna being shielded from the radar station. With several key radar returns missing, the distance between points is far less than the distance actually flown by the test airplane. For an unknown reason, the more southerly of the two steep turns was only missing one return. In Figure 4, the calculated bank angle history for this maneuver is shown. Notice that the first turn is reconstructed very accurately compared to the second steep turn; however, the results presented in Table 3 include the errors from both turns. This example shows the importance of critically studying the radar data before accepting the results.

Many accident flight paths are composed of some essentially straight segments and other segments in which the airplane is maneuvering. This study showed that the best smoothing levels are different for straight and maneuvering flight. Therefore, it is possible that using one level of smoothing for an entire accident flight can cause some portion(s) of the analysis to have significant errors. As a result, it would be prudent for the reconstructionist to break the flight into segments of similar characteristics and apply different smoothing levels and calculation techniques to each segment.

It should be noted that the above results were obtained using radar data that was recorded by an airport surveillance radar (ASR) system, which produces a return approximately every 4.6 seconds. Enroute radar, which is recorded by an Air Route Traffic Control Center (ARTCC), has lower resolution and frequency, producing a return approximately every 12 seconds. Results may vary when reconstructing flight paths and flight parameters from ARTCC radar returns.

		Flight Parameter Mean Absolute Error Chart – Steep Turns					
		Ground Speed (knots)	True Airspeed (knots)	Mag. Heading (deg)	Load Factor (G's)	Bank Angle (deg)	Turn Rate (deg/sec)
Rectilinear	No Smoothing	18.35212	12.71593	18.51295	0.11888	9.65075	4.13567
	5 Pt. LS	9.99653	18.92485	11.50448	0.11365	6.69572	1.72731
	9 Pt. LS	20.76229	40.14749	28.88448	0.18576	17.51656	2.08715
	13 Pt. LS	40.82651	58.38009	78.05147	0.2303	24.60373	2.87949
Curvilinear	No Smoothing	26.34695	10.94298	18.15925	0.12995	9.84918	4.26664
	5 Pt. LS	20.28198	9.78388	27.31151	0.10929	7.40807	1.97936
	9 Pt. LS	19.00798	23.15021	36.3075	0.18711	12.61575	2.30611
	13 Pt. LS	27.57412	45.3692	53.63772	0.23005	18.88918	3.1964

		Flight Parameter Mean Absolute Error Chart – Chandelles					
		Ground Speed (knots)	True Airspeed (knots)	Mag. Heading (deg)	Load Factor (G's)	Bank Angle (deg)	Turn Rate (deg/sec)
Rectilinear	No Smoothing	14.14579	8.01349	34.36324	0.14046	7.17092	2.79559
	5 Pt. LS	5.64874	11.26556	33.70065	0.10198	5.02349	1.44511
	9 Pt. LS	18.05566	29.41249	42.53529	0.14774	9.31308	1.78414
	13 Pt. LS	42.89118	53.43205	45.82314	0.17867	13.80657	1.88668
Curvilinear	No Smoothing	19.0504	8.86161	34.60733	0.14254	7.34091	2.89989
	5 Pt. LS	16.73912	8.37561	34.4225	0.09244	4.72105	1.68774
	9 Pt. LS	13.53835	14.99505	43.22195	0.13008	8.1322	2.0667
	13 Pt. LS	13.82653	25.00995	44.22117	0.1719	11.69751	2.12529

		Flight Parameter Mean Absolute Error Chart – Instrument Approach					
		Ground Speed (knots)	True Airspeed (knots)	Mag. Heading (deg)	Load Factor (G's)	Bank Angle (deg)	Turn Rate (deg/sec)
Rectilinear	No Smoothing	2.78811	8.837	3.29071	0.08193	5.20265	2.69483
	5 Pt. LS	1.08927	8.72813	3.08301	0.04712	2.76674	1.6307
	9 Pt. LS	1.05824	8.06803	3.29408	0.04314	2.98421	1.65581
	13 Pt. LS	2.08154	7.88153	3.46758	0.04236	3.2789	1.62976
Curvilinear	No Smoothing	3.00619	9.53601	3.29556	0.08183	5.21005	2.69804
	5 Pt. LS	2.0043	9.17007	3.08795	0.05397	2.82474	1.6559
	9 Pt. LS	1.2104	8.92506	3.19427	0.04716	2.99577	1.68532
	13 Pt. LS	1.41441	8.64691	3.32823	0.04354	3.2789	1.62976

		Flight Parameter Mean Absolute Error Chart – Autopilot Turn					
		Ground Speed (knots)	True Airspeed (knots)	Mag. Heading (deg)	Load Factor (G's)	Bank Angle (deg)	Turn Rate (deg/sec)
Rectilinear	No Smoothing	4.35232	9.21009	21.96574	0.0539	6.25281	2.80609
	5 Pt. LS	2.46616	8.05755	21.69014	0.04892	1.93921	1.35634
	9 Pt. LS	2.06705	5.48878	22.2243	0.0453	2.90897	1.35978
	13 Pt. LS	6.9976	7.54385	23.7429	0.04739	6.02677	1.35198
Curvilinear	No Smoothing	4.94585	9.98166	21.97889	0.05433	6.28521	2.81417
	5 Pt. LS	4.47992	9.80602	21.88181	0.05166	2.20816	1.41083
	9 Pt. LS	3.35942	9.58649	21.75405	0.04746	3.23088	1.3449
	13 Pt. LS	2.40039	7.14693	22.43618	0.04824	5.80386	1.38054

Table 3. Flight Parameter Mean Absolute Error Results

V. CONCLUSIONS

The data recorded on board the test airplane proved to be a valuable tool to help determine the optimal level of smoothing and best calculation method for each maneuver. Assuming that those data were "true" representations of the flight path and flight parameters of the test flight, the calculation techniques and smoothing levels were quantitatively evaluated. The largest source of error in the calculation of true airspeed and heading was in the accuracy of the wind profile that was used.

The results showed that, in general, it is best to use a high level of smoothing for nearly straight flight and minimal smoothing (but not zero smoothing) for maneuvering flight. It was also found that, in general, the curvilinear approach provided slightly better results than the rectilinear approach for maneuvering flight. Unfortunately, many accident flight paths are composed of segments which are essentially straight and other segments in which the airplane is maneuvering, so it may be appropriate to break the flight into

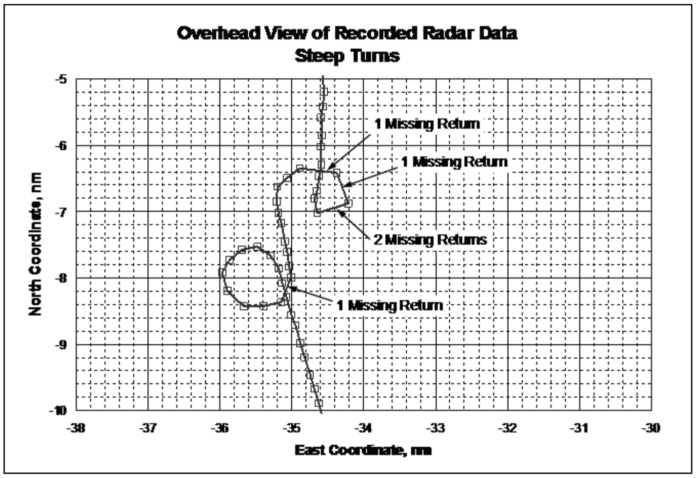

Figure 3. Ground track during steep turns.

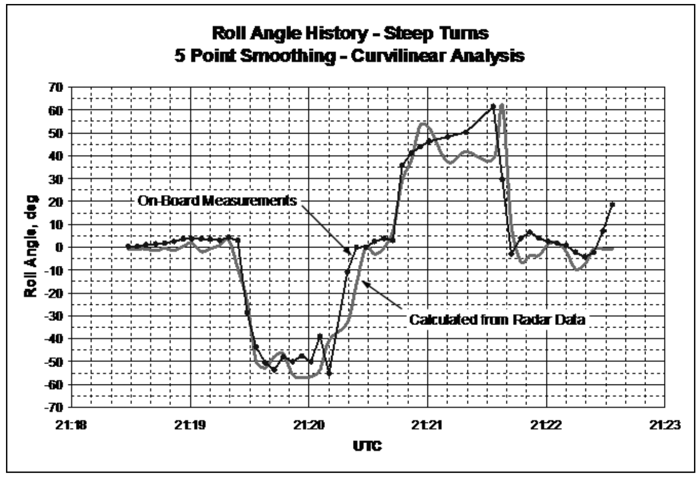

Figure 4. Calculated and measured bank angle during steep turns.

segments and use different smoothing levels in each segment.

It is likely that some returns will be missing from a set of radar data, and those missing returns may result in calculations that have significant errors. The solution to this problem will likely vary with the unique aspects of each analysis; however, it is a bsolutely essential to use valid engineering judgment in assessing the significance of any missing returns. ◆

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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

Philippe Plantin of Hugues *was awarded his Ph.D. in fluid mechanics in 1991. In 1992 he spent one year at the NASA Ames Research Center and then joined the BEA Engineering Department in 1993 to oversee acoustic analysis. He has participated in all the major international investigations involving France since then. He has been the chairman and French representative on the OACI /FLIRECP, the chairman of the EUROCAE WG-50 (ED-112), and the chairman of the EUROCAE WG-77 that published ED-155.*

1. Introduction

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 which has now defined specifications for lightweight flight recorder systems. Any future regulations applicable to small aircraft under 5.7 tons will reference these specifications.

This paper will show how accident prevention in GA could be improved by more widespread use of lightweight flight recorders, especially through flight data monitoring, instruction, flight simulation, and leisure activities.

2. Statistics

Almost 79,000 aircraft under 5.7 tons are active in Europe (source EASA) and nearly three times as many in the United States (source GAMA).

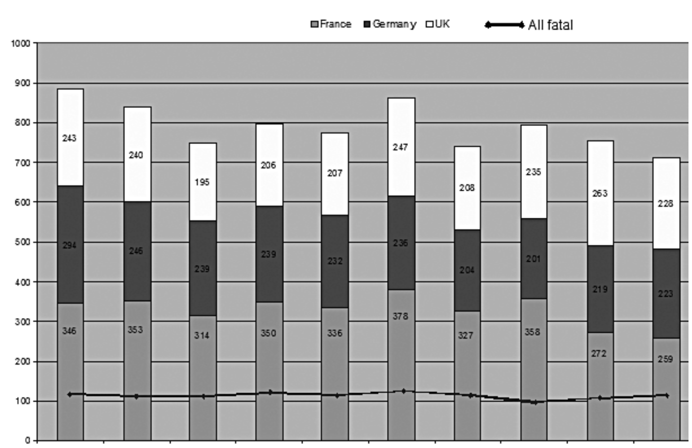

Figure 1. Number of accidents during the last 10 years. (Source: BEA, BFU, and CAA)

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 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 tones (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.

3. 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 man ufacturers to find out which parameters 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. This data can be acquired in several ways according to the airplane's technology and the objective:

- in a stand-alone 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.
- by recovering all the data passing through the bus installed on more recent aircraft.

Figure 2

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 the understanding of accidents.

4. Example of an investigation using an audio and video recording

On Jan. 6, 2003, at Chambéry Challes the Eaux (France), shortly after take off 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:

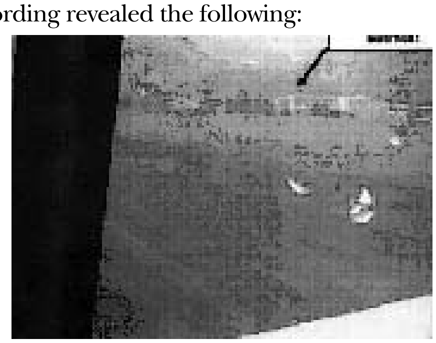

Figure 3

- 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.
- 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 video tape 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 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.

5. 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 in this paper.

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 (FDM) 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 for post flight data analysis services should not be exceeded.

The conclusion of the study is that

- flight data monitoring (FDM) as part of Safety Management Systems (SMSs) 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 a 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.

6. 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 data-link 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, manufacturer, 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.

Even if the primary objective of this document is to provide specifications to be referenced by a regulatory authority, it has four objectives, some of which fall outside the scope of any regulation.

We hope to develop a single standard meeting these 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 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 an 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 an airborne image recording systems (AIRS), the audio quality to capture the voices of the pilots on a 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.

7. The advantages in terms of aviation safety

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 (Figure 4).

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,
- systematic flight analysis, with automatic detection where safety thresholds are exceeded,
- precise billing of flying hours,
- simplification of management and administrative structure, and
- drop in insurance premiums.

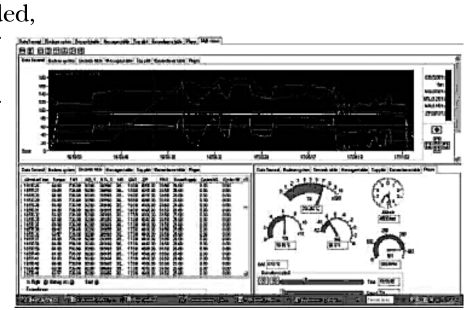

Figure 4

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 including

- simple simulation of the training flight with software associ-

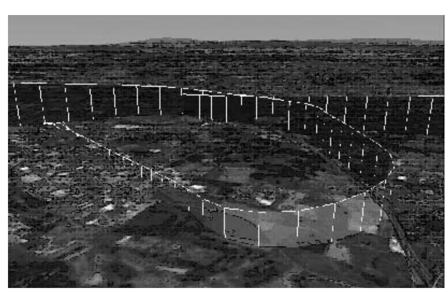

Figure 5

ated 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
• 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 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.

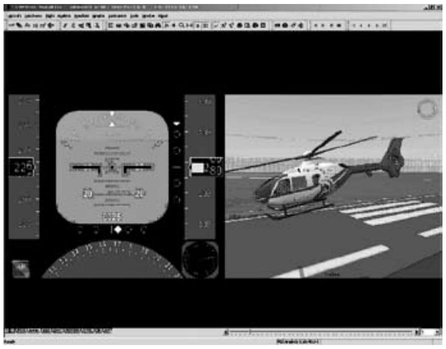
Figure 6

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 the initial investment being offset in a few short years.

8. 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. ◆

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

__David Zwegers__ is the director of aviation safety at Embry-Riddle Aeronautical University's Daytona Beach campus. Born in the Netherlands and raised in Spain, this married father of two has flown more than 3,500 accident-free hours of flight time with almost 3,000 hours of flight instructor time. He graduated from ERAU with a BS in aeronautical science and is in the process of 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. During his 11 years of employment at ERAU, Zwegers has held positions as a flight instructor, pilot examiner, and training manager. He was chief of flight standards at the U.S. Air Force Academy. Zwegers is responsible for the safety program at ERAU in Daytona Beach, which flies more than 75,000 hours per year, operates a fleet of 65 aircraft, conducts an average of 300 flights per day, and safely manages the training of 1,000 flight students and 180 flight instructors. In October 2008, he was awarded the John K. Lauber Safety Award by the University Aviation Association.

Abstract

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.

Also, unlike radar, ADS-B accuracy does not seriously degrade with range, atmospheric conditions, or target altitude, and update intervals do not depend on the rotational speed or reliability of mechanical antennas. ADS-B capable aircraft use an ordinary GNSS (GPS, Galileo, etc.) receiver to derive its precise position from the GNSS constellation then combine that position with any number of aircraft (or any other vehicle) discretes, such as speed, heading, altitude and registration number. This information is then simultaneously broadcast to other ADS-B capable aircraft and to ADS-B ground or satellite communications transceivers that then relay the aircraft's position and additional information to air traffic control centers in real time.

ADS-B software applications allow traffic and weather information to be displayed in real time, on personal computers on the ground via the Internet. This information can be recorded and utilized for accident investigations and prevention at a very low cost and ease of use. It could be viewed as a variation of FOQA for general aviation. Some software applications can also record ATC radio communications, providing a valuable amount of information.

ERAU has had ADS-B installed on its fleet of more than 100 training aircraft since 2003, which has proven to be an invaluable tool in enhancing overall pilot situational awareness and minimizing the risk of flight training in a saturated environment.

As ADS-B is implemented by aviation agencies and industry worldwide, the advances of hardware and software will bring a new level of safety in the air and on the ground.

Because the possibilities of ADS-B technology are endless and easily customized to each operator, this presentation will focus on ERAU's past and current applications of ADS-B technology over the years, and future initiatives. Specific examples will be presented with visual aids and practical applications.

What is ADS-B?

ADS-B is the acronym for Automatic Dependent Surveillance-Broadcast—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.

Automatic—It's always ON and requires no operator intervention.

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

Surveillance—It provides "radar like" surveillance services, much like radar.

Broadcast—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 com-

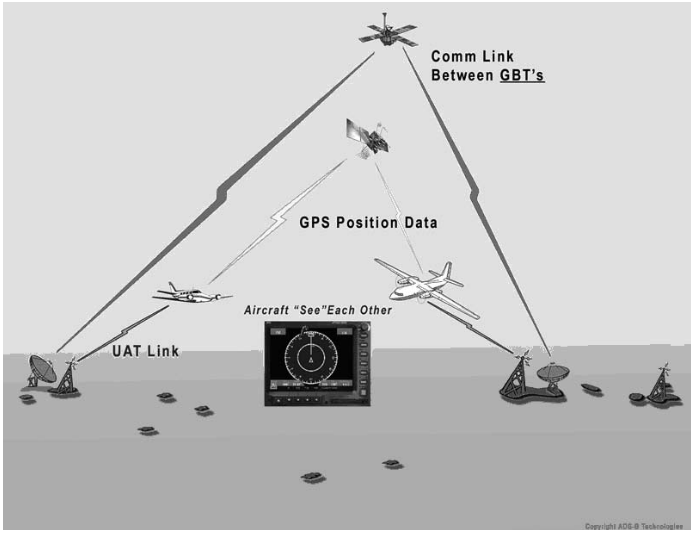

Figure A

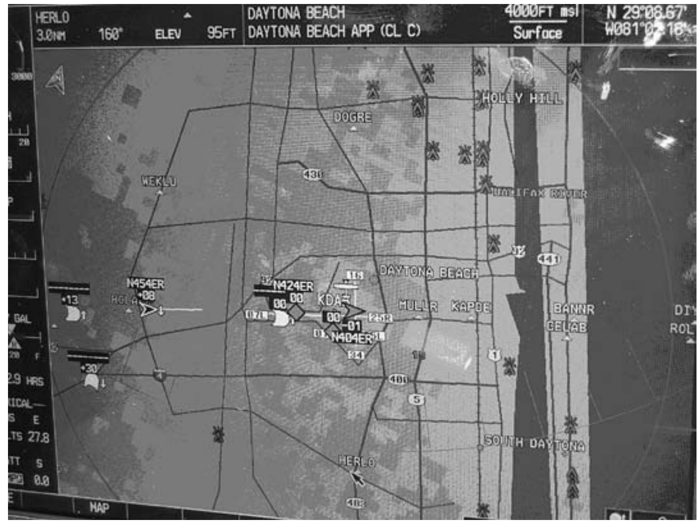

Figure C

Figure B

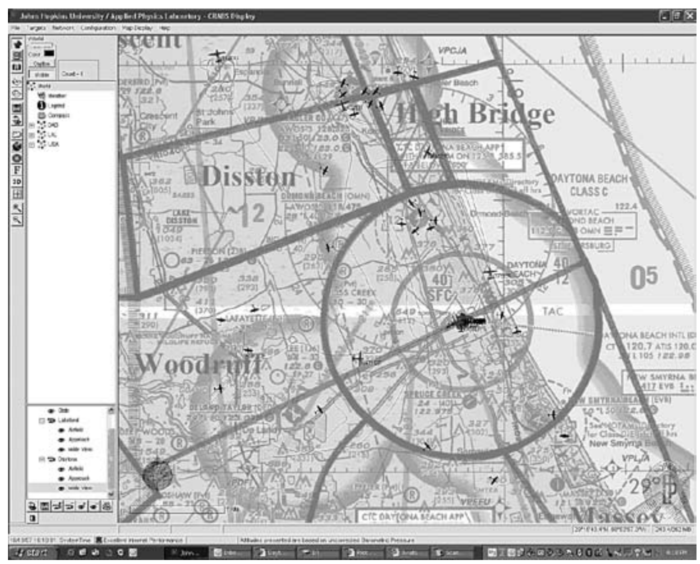

Figure D

bined 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 multi-function 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 broadcasts and display the information in 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 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).
- 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.

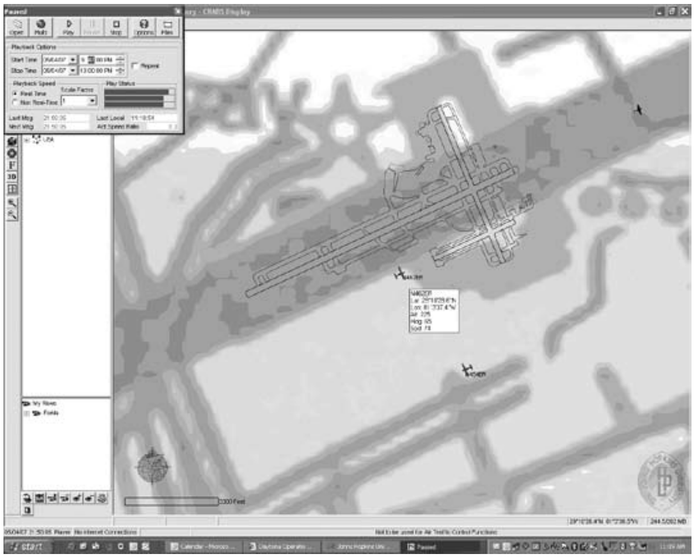

Figure 1

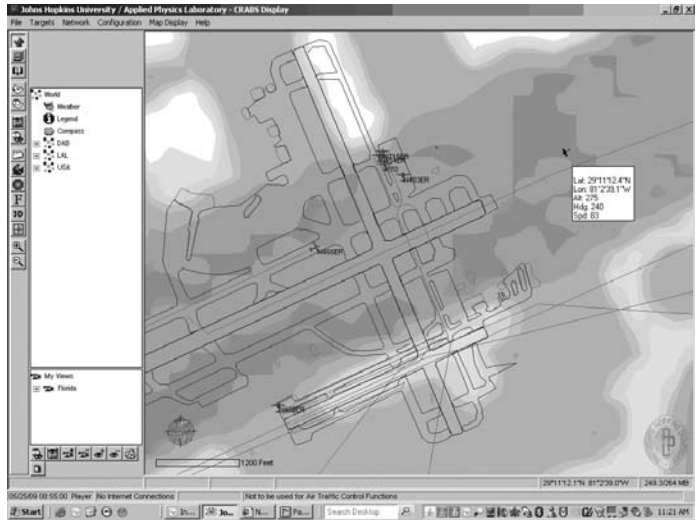

Figure 3

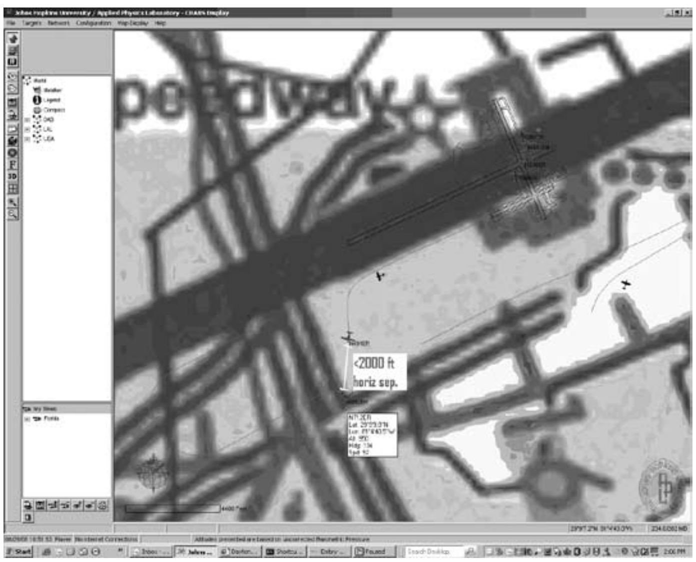

Figure 2

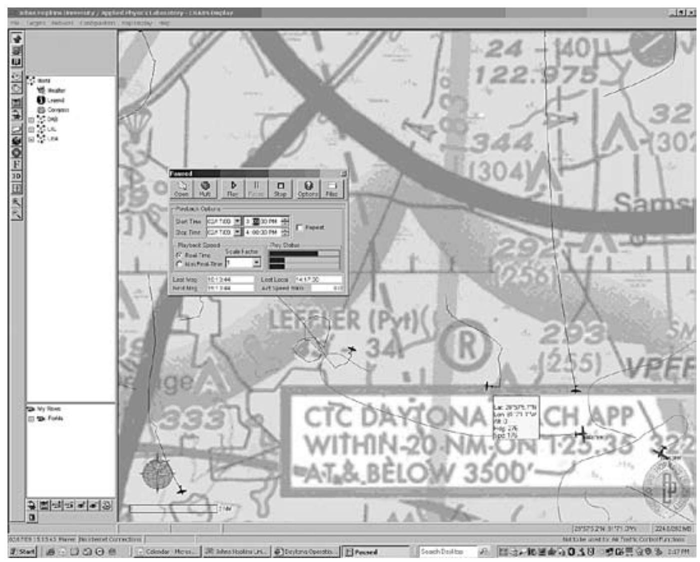

Figure 4

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, the 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.

NTSB probable cause: Pilot's improper flare at night. Contribut-

Figure 5

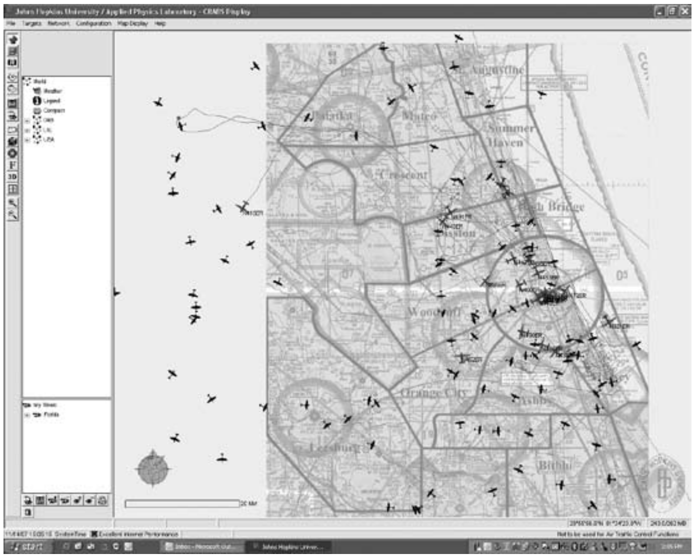

Figure 6

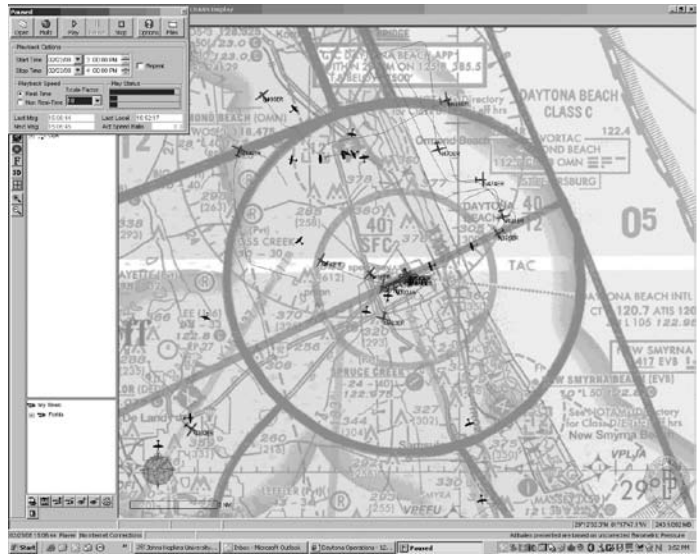

Figure 8

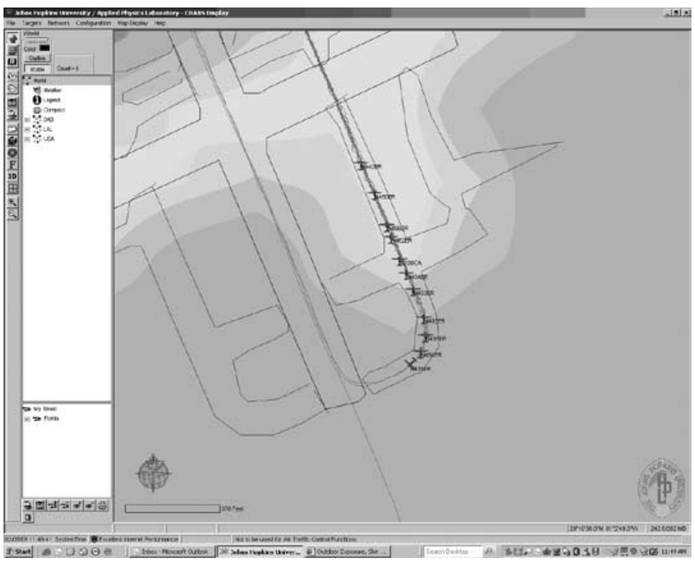

Figure 7

ing factor was a lack of recent night experience.

RABS 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 EFB 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 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 contribute 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 injured. CRABS assisted investigators in determining probable cause.
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.

Case #4. Noise complaints and airspace violations.
ADS-B assists ERAU in the enforcement of noise abatement agreements and also protects pilots and operators against false identification or unjust noise complaints.

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.

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 establishing communications with 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 is 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 of it, 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. ◆

Human Error Prevention: Using the Human Error Template To Analyze Errors in a Large Transport Aircraft for Human Factors Considerations

By Wen-Chin Li, Topic Presenter, 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

Wen Chin Li *"Topic Presenter," Head of Graduate School of Psychology, National Defense University, Taiwan. (photos and biographical information of other authors not available.)*

Abstract

Flight crews make positive contributions to the safety of aviation operations. Pilots have to assess continuously changing situations, evaluate potential risks, and make quick decisions. However, even well-trained and experienced pilots make errors.

Accident investigations have identified that pilots' performance is influenced significantly by the design of the flightdeck interface. This research applies hierarchical task analysis (HTA) and utilizes the Human Error Template (HET) taxonomy to collect error data from pilots during flight operations when performing a go-around in a large commercial transport aircraft. HET was originally developed in response to a requirement for formal methods to assess compliance with the new human factors certification rule for large civil aircraft introduced to reduce the incidence of design-induced error on the flight deck (EASA Certification Specification 25.1302). The HET taxonomy was applied to each bottom-level task step in an HTA of the flight task in question.

A total of 67 pilots participated in this research including 12 instructor pilots, 18 ground training instructor, and 37 pilots. Initial results found that participants identified 17 operational steps with between two and eight different operational errors being identified in each step by answering questions based either on his/her own experience or their knowledge of the same mistakes made previously by others. Sixty-five different errors were identified.

The data gathered from this research will help to improve safety when performing a go-around by identifying potential errors on a step-by-step basis and allowing early remedial actions in procedures and crew coordination to be made.

Key Words: Aviation safety, human errors, hierarchical task analysis, human error template

Introduction

For the past half century, there has been a steady decline in the commercial aircraft accident rate. Nevertheless during the last decade or so the serious accident rate has remained relatively constant at approximately one per million departures (Boeing, 2008). While high levels of automation in third-generation airliners have undoubtedly contributed considerable advances in safety over earlier jet transport aircraft, new types of error have emerged on these flight decks (Woods and Sarter, 1998). These types of accident are exemplified in crashes such as the Nagoya Airbus A300-600 (in which the pilots could not disengage the go-around mode after its inadvertent activation; this was as a result of a combination of lack of understanding of the automation and poor design of the operating logic in the autoland system); the Cali Boeing 757 accident (in which the poor interface on the flight management computer and a lack of logic checking resulted in a CFIT accident); and the Strasbourg A320 accident (in which the crew inadvertently set an excessive rate of descent instead of manipulating the flight path angle as a result of both functions utilizing a common control interface and an associated poor display). Human error is now the principal threat to flight safety. In a worldwide survey of causal factors in commercial aviation accidents, in 88% of cases the crew was identified as a causal factor; in 76% of instances, the crew was implicated as the primary causal factor (CAA, 1998).

The skills now required to fly a large commercial aircraft have changed considerably during the past three decades, mostly as a direct result of advances in control and display design and the technology of automation. The pilot of a modern commercial aircraft is now a manager of the flight crew and of complex, highly automated aircraft systems. The correct application of complex procedures to manage activities on the flight deck is now an essential part of ensuring flight safety. Most aspects of flight management are now highly procedurally driven. While pilot error is without doubt now the major contributory factor in aircraft accidents, a diagnosis of "error" in itself says very little. It is not an explanation; it is merely the beginning of an explanation. Dekker (2001) proposed that errors are systematically connected to many features of a pilot's tools and tasks and that the notion of "error" itself has its roots in the surrounding socio-technical system associated with aircraft operations. The question of human error or system failure alone is an oversimplification. The causes of error are many and varied and almost always involve a complex interaction among the pilot's actions, the aircraft flight deck, the procedures to be employed, and the operating environment.

During the last decade "design induced" error has become of particular concern to the airworthiness authorities, particularly in the highly automated third- and fourth-generation airliners. A Federal Aviation Administration (FAA) commissioned study of the pilot-aircraft interface on modern flight decks (FAA, 1996) identified several major design deficiencies and shortcomings in the design process. There were criticisms of the flight deck interfaces, identifying problems such as pilots' autoflight mode awareness/indication; energy awareness; position/terrain awareness; confusing and unclear display symbology and nomenclature; a lack of consistency in FMS interfaces and conventions, and poor compatibility between flightdeck systems. The U.S. Department of Transportation (DOT) subsequently assigned a task to the Aviation Rulemaking Advisory Committee (ARAC) to provide advice and recommendations to the FAA administrator to "review the existing material in FAR/JAR 25 and make recommendations about what regulatory standards and/or advisory material should be updated or developed to consistently address design-related flight crew performance vulnerabilities and prevention (detection, tolerance and recovery) of flight crew error" (U.S. DOT, 1999). Since September 2007, rules and advisory material developed from ARAC tasking have been adopted by EASA (European Aviation Safety Agency) as Certification Specification (CS) 25.1302 and with supporting advisory material in AMC (Acceptable Means of Compliance) 25.1302.

Perhaps the true significance of the establishment this regulation is that for the first time there is a specific regulatory requirement for "good" human factors on the flight deck. It is an attempt to eradicate many aspects of pilot error at source. However, such rules relating to design can only address the fabric of the airframe and its systems so the new regulation can only minimize the likelihood of error as a result of poor interface design. It cannot consider errors resulting from such factors the inappropriate implementation of procedures, etc. From a human factors viewpoint, which assumes that the root causes of human error are often many and interrelated, the new regulations have only addressed one component of the wider problem. The design of the flightdeck interfaces cannot be separated from the aircraft's operating procedures. Complex flightdeck interfaces, while potentially more flexible, are also potentially more error prone (there are far more opportunities for error). Analysis of aircraft accident investigation reports has suggested that inappropriate system design, incompatible cockpit display layout, and unsuitable standard operating procedures (SOPs) are major factors causing accidents (FAA, 1996).

With regard to checklists and procedures, various axioms have been developed over the years. For example, Reason (1988) observed that the larger the number of steps in a procedure, the greater the probability that one of them will be omitted or repeated; the greater the information loading in a particular step, the more likely that it will not be completed to the standard required; steps that do not follow on from each other (i.e., re not functionally related) are more likely to be omitted; a step is more likely to be omitted if instructions are given verbally (for example in the "challenge and response" format used on the flight deck); and interruptions during a task that contains many steps are most likely to cause errors. Li and Harris (2006) found that 30% of accidents relevant to "violations" in military aviation included intentionally ignoring SOPs, neglecting SOPs, applying improper SOPs, and diverting from SOPs. The figure was higher in commercial aviation, with almost 70% of accidents including some aspect of a deviation (or non-adherence) to SOPs (Li, Harris and Yu, 2008).

Formal error identification techniques implicitly consider both the design of the flightdeck interfaces and the procedures required to operate them simultaneously. They can be applied at early design stages to help avoid design-induced error during the flightdeck design process, but they can also be used subsequently during flight operations to diagnose problems with SOPs and provide a basis for well-founded revisions. Formal error identification analysis is not new. It has been used in the nuclear and petrochemical industries for many years. Most formal error identification methods operate in a similar way. They are usually based on a task analysis followed by the subsequent assessment of the user interfaces and task steps to assess their error potential. However, it should be noted that formal error prediction methodologies only really address Reason's skill-based (and perhaps some rule-based) errors within a fairly well-defined and proceduralized context. Hence they can only help in protecting against errors that relate either to the flightdeck interfaces or their directly associated operating procedures.

HET, developed by Marshall, Stanton, Young, Salmon, Harris, Demagalski, Waldmann, and Dekker (2003) is a human error identification (HEI) technique designed specifically for application on the aircraft flight deck. Advisory Circular AC25.1309-1A (FAA, 1988) suggested that the reliable quantitative estimation of the probability of crew error was not possible. As a result, HET was developed specifically for the identification of potential errors using formal methods, not their quantification. It was developed as a diagnostic tool intended as an aid for the early identification of design-induced errors, and as a formal method to demonstrate the inclusion of human factors issues in the design and certification process of aircraft flight decks. HET has been demonstrated to be a reliable and valid methodology (see Stanton, Harris, Salmon, Demagalski, Marshall, Young, Dekker, and Waldmann, 2006; Stanton, Salmon, Harris, Marshall, Demagalski, Young, Waldmann and Dekker, 2009). It has been benchmarked against three existing techniques (SHERPA—Systematic Human Error Reduction and Prediction Approach, Embry, 1986; Human Error HAZOP—Hazard and Operability study, Whalley, 1988; and HEIST—Human Error In Systems Tool, Kirwan, 1988) and outperformed all of them in a validation study comparing predicted errors to actual errors reported during an approach and landing task in a modern, highly automated commercial aircraft. The HET method has been proven to be simple to learn and use, requiring very little training, and it is also designed to be a convenient method to apply in a field study. The error taxonomy used is comprehensive as it is based largely on existing error taxonomies from a number of HEI methods but has been adapted and extended specifically for the aerospace environment.

The International Air Transport Association (IATA) analyzed data

Sub-task for performing Go-around by HTA / Error Modes		Fail to execute	Task execution incomplete	Task executed in wrong direction	Wrong task executed	Task repeated	Task executed on wrong interface element	Task executed too early	Task executed too late	Task executed too much	Task executed too little	Misread information	Other
1.1.1	Press TO/GA Switches	33.93	16.07	7.34	26.79	16.07	7.34	16.07	25.00	1.79	0.00	1.79	3.57
1.1.2	Thrust has advanced	26.79	48.21	0.00	0.00	0.00	0.00	5.36	5.36	10.71	0.00	5.36	8.93
1.2.1	PF command flap 20	42.86	12.50	0.00	5.36	0.00	0.00	3.57	42.86	1.79	1.79	0.00	0.00
1.2.2	PM place flap lever to 20	19.64	14.29	10.71	5.36	0.00	3.57	5.36	19.64	3.57	0.00	0.00	7.14
1.3.1	Verify TO/GA mode annunciation	48.21	26.79	1.79	1.79	0.00	5.36	0.00	8.93	0.00	1.79	12.50	7.14
1.3.2	Rotate to proper pitch attitude	5.36	39.29	3.57	1.79	1.79	0.00	5.36	25.00	35.71	8.93	3.57	1.79
1.4.1	Verify adequate thrust for go-around	53.57	39.29	7.14	5.36	0.00	0.00	3.57	8.93	1.79	3.57	10.71	3.57
1.4.2	Announce go-around thrust set	62.50	26.79	0.00	1.79	0.00	0.00	1.79	12.50	0.00	3.57	0.00	0.00
1.5.1	Verify positive rate of climb	32.14	19.64	7.14	0.00	0.00	0.00	1.79	23.21	0.00	0.00	0.00	12.50
1.5.2	Place gear lever to up	39.29	7.14	5.36	3.57	0.00	1.79	19.64	42.86	0.00	0.00	0.00	8.93
1.6.1	Select Roll mode	26.79	14.29	14.29	10.71	0.00	8.93	5.36	51.79	0.00	0.00	3.57	3.57
1.6.2	Verify Roll mode annunciation	35.71	23.21	1.79	3.57	0.00	0.00	0.00	37.86	0.00	3.57	3.57	8.93
1.6.3	Turn into correct track	5.36	28.57	10.71	5.36	0.00	1.79	5.36	51.07	3.57	0.00	0.00	3.57
1.7.1	Select Pitch mode	23.21	26.79	23.21	5.36	0.00	3.57	8.93	50.00	1.79	1.79	3.57	3.57
1.7.2	Verify Pitch mode annunciation	26.79	26.79	3.57	3.57	0.00	0.00	1.79	21.43	0.00	3.57	0.00	10.71
1.7.3	Maintain proper pitch attitude	12.50	46.43	12.50	1.79	0.00	1.79	1.79	21.43	7.14	8.93	3.57	1.79
1.8	Follow M/A Procedure	10.71	50.00	25.00	17.86	0.00	7.14	8.93	30.36	0.00	0.00	12.50	3.57

Table 1: The Results for the Human Error Modes in Aircraft X When Performing a Go-Around. Numbers in the Cells Show Percentage (%) of Respondents Reporting that Error Mode in Each Task Step

from 240 member airlines and found about 50% of accidents in 2007 occurred during the phrases of final approach and landing, a period that comprises (on average) only 4% of the total flight time. Most pilots are trained that executing a go-around is the prudent course of action when a landing is not progressing normally and a safe outcome is not ensured. This is the best practice, but it isn't always a straightforward decision (Li and Harris, 2008). Knowing how to execute the go-around maneuver and being proficient in its execution are extremely important but still more is required. Pilots must possess the skill and knowledge to decide when to execute a go-around. Many accidents have happened as a result of hesitating too much before deciding to abort the landing. This research applies the Human Error Template (Marshall, Stanton, Young, Salmon, Harris, Demagalski, Waldmann and Dekker (2003) to the retrospective analysis of go-around procedures in a large commercial aircraft to identify potential areas for improvement in the design of the SOPs involved.

Method

Participants: Sixty-seven pilots participated in this research, including 25 captains and 42 first officers. Twenty-one pilots had in excess of 10,000 flight hours; 18 pilots had between 5,000 and 9,999 hours; 17 pilots had between 2,000 and 4,999 hours, and 11 pilots had below 1,999 flying hours. There were 12 instructor pilots, 18 ground training instructors, and 37 pilots with teaching experience. The age range of participants was between 28 and 60. All participants held a type-rating for the large jet transport aircraft under consideration.

Description of the task: The first step in this research was conducting a hierarchical task analysis (HTA) to define clearly the task under analysis. The purpose of the task analysis in this study was an initial step in the process of reviewing the integration of hardware design, standard operations procedures, and pilots' actions during a go-around. The task analysis undertaken was for the go-around on a large, four-engined, inter-continental jet transport aircraft (aircraft X)

Task decomposition: Go-around operations can be considered as the required actions to be made by a pilot to achieve the associated goal and based on the SOPs. Once the overall task goal (safely performing go-around) had been specified, the next step was to break this overall goal down into meaningful sub-goals, which together formed the tasks required to achieve the overall goal (Annett, 2005). In the task, "safely performing a go-around," this overall goal was broken down into the sub-goals, for example: 1.1 Press TO/GA Switches, 1.2 Set Flaps Lever to 20, 1.3 Rotate to Go-around Attitude, 1.4 Verify Thrust Increase, 1.5 Gear up, 1.6 Select Roll Mode, 1.7 Select Pitch Mode, and 1.8 Follow Missed Approach Procedures. The analysis of each task goal was broken down into further sub-goals, and this process continued until an appropriate operation was reached. The bottom level of any branch in a HTA should always be an operation. For example, the sub-goal 1.7 Select Pitch Mode was broken down into the following operations: 1.7.1 Select Pitch Mode, 1.7.2 Verify Pitch Mode Annunciation, and 1.7.3 Maintain Proper Pitch Attitude. Seventeen bottom level tasks were identified in this analysis.

Classifying modes of error: HET is a checklist-style approach to error prediction utilizing an error taxonomy comprised of 12 basic error modes. The taxonomy was developed from reported instances of actual pilots and extant error modes used in contemporary HEI methods. The HET taxonomy is applied to each bottom level task step in a hierarchical task analysis (HTA) of the flight task in question. The technique requires the analyst to indicate which of the HET error modes are credible (if any) for each task step, based upon their judgment (Harris, Stanton, Marshall, Young, Demagalski & Salmon, 2005). There are 12 basic HAT error modes: "Failure

Modes of Error	Description of Errors Occurred during Go-Around	Occurrence rate		
		ME	OTHERS	AVERAGE
Fail to execute	Q5. Failed to check thrust level	38.81%	56.72%	47.76%
Task execute incomplete	Q8.Thrust lever were not advanced manually when the auto-throttles became inoperative	29.85%	53.73%	41.79%
Fail to execute	Q9. Failed to command 'flap 20' due to pilot's negligence	25.37%	67.16%	46.26%
Fail to execute	Q15. Failed to check whether TO/GA mode was being activated	44.78%	46.27%	45.53%
Task execute too late	Q17. Late rotation, over / under rotation.	46.27%	50.75%	48.51%
Task execute incomplete	Q18. No check for primary flight display	26.87%	56.72%	41.79%
Fail to execute	Q23. Failed to check go-around thrust setting	53.73%	52.24%	52.99%
Task execute too late	Q25. Did not identify and correct speed deviations on time	46.27%	47.76%	47.015%
Fail to execute	**Q26. Forgot to call 'go-around thrust set'**	**68.66%**	**70.15%**	**69.41% (1)**
Task execute too late	Q27. Did not identify and correct go-around thrust deviations on time	35.82%	58.21%	47.02%
Fail to execute	Q30. Forgot to put the landing gear up until being reminded	40.30%	59.70%	50%
Task execute too late	**Q33. Did not engage LNAV mode on time failed to capture**	**49.25%**	**58.21%**	**53.73% (3)**
Fail to execute	Q37 Failed to check whether LNAV/ HDG was being activated	31.34%	64.18%	47.76%
Task execute on wrong interface	Q39. Mixed up the IAS/HDG bugs on the MCP	34.33%	49.25%	41.79%
Fail to execute	Q42. Did not engage VNAV mode on time failed to capture	44.78%	62.96%	53.37%
Task execute incomplete	Q46. No check whether VNAV or FLCH was being activated	38.81%	56.72%	47.76%
Task execute incomplete	Q48. Did not monitor the altitude at appropriate time	38.81%	55.22%	47.02%
Task execute too little	Q62 Poor instrument scan	43.28%	55.22%	49.25%
Task execute incomplete	**Q65. Not using auto-flight system when available and appropriate.**	**55.22%**	**65.67%**	**60.45% (2)**

Table 2: The Occurred Rates of Error Break Down by Detail Operational Behaviors for Aircraft X Performing Go-around (Shown the Average Error More than 40% for Both ME and OTHERS)

Scenario: Go-around at XXX International Airport			Task step: 1.3.2 Rotate to proper pitch attitude								
Error mode	Tick	Description	Outcome	Likelihood			Criticality			PASS	FAIL
				H	M	L	H	M	L		
Fail to execute	V	Pilot's incapability when A/P engaged	A/C not climbing and speed increasing	V			V				V
Task execution incomplete	V	Failed to trim to prevent excessive pitch up /failed to trim to reduce forward pressure	Not enough climb rate/speed too high	V			V				V
Task executed in wrong direction	V	Failed to rotate to target go-around pitch first or follow F/D without crosscheck SPD	Affect go-around performance SPD too high/ too low		V			V		V	
Wrong task executed	V	Banking instead of pitching up	A/C not climbing but rolling, may cause wings not level		V			V		V	
Task repeated											
Task executed on wrong interface element											
Task executed too early	V	Rotate to proper pitch too rapidly	Airspeed low		V		V			V	
Task executed too late	V	Rotate to proper pitch too slowly	Affect go-around performance may cause not enough climb rate	V			V				V
Task executed too much	V	Increase pitch too high	Airspeed low	V				V		V	
Task executed too little	V	Increase pitch not enough	Not enough climb rate	V					V	V	
Misread information	V	Misreading pitch attitude	May cause unstable climb rate			V			V	V	
Other											

Table 3: An Example of Human Error Template Output from Sub-Task Step 1.3.2 "Rotate to Proper Pitch Attitude" for Performing a Go-Around

to execute," "Task execution incomplete," "Task executed in the wrong direction," "Wrong task executed," "Task repeated," "Task executed on the wrong interface element," "Task executed too early," "Task executed too late," "Task executed too much," "Task executed too little," "Misread Information," and "Others." A full description of the methodology and all materials can be found in Marshall, Stanton, Young, Salmon, Harris, Demagalski, Waldmann, and Dekker (2003).

The design of evaluating format: These 17 bottom-level tasks are broken down into 65 operational items to be evaluated by all participants using a structured questionnaire. The questionnaire format asked participants if they had ever made the reported error (checked "ME") and if they also had observed any one else who had made the error (checked "OTHER"). It was hoped that this format would increased the participant's confidence in being able to report errors. For example, if they had made the error themselves but had no desire to admit to making the error, they could check the "OTHERS" box.

Results and discussion

Participants responded to items based upon 17 sub-tasks in which each step could include any one (or more) of 12 different types of human errors (see Table 1). Each sub-task consisted of operational behaviors for participants to evaluate based on his/her own experience (ME) or if he/she knew someone who had committed the errors (OTHERS).

There were 19 task steps with a very high percentage of errors during go-around (defined as being when the average number of errors for both ME and OTHERS was more than 40%). (See Table 2.) The most common error mode for pilots performing the go-around was "Failure to execute," the second highest was "Task execution incomplete," the third highest was "Task executed too late." (See Table 2). The most commonly occurring operational error of pilots when performing the go-around was "Forgot to call Go-around Thrust Set" (average 69.41%); the second highest was "Not using autoflight system when available and appropriate" (average 60.45%); the third most common error reported was "Did not engage LNAV mode on time failed to capture" (average 53.73%).

These 17 bottom-level sub-tasks were further evaluated by all participants. For each credible error identified, a description of the form that the error would take was required and the outcome or consequence associated with the error was determined. The likelihood of the error was estimated using a very simple scale (low, medium, or high) as was the criticality of the error (low, medium, or high). If an error was given a high rating for both likelihood and criticality, the task step was then rated as a "fail," meaning that the procedure involved should be examined further and it should

Scenario: **Performing a Go-around at XXX International Airport**			Operational step: **1.3.2 Rotate to proper pitch attitude**	
Error Mode	**Description**	Frequency	**Outcome**	Frequency
Fail to execute	PF's negligence from surrounding interference (2) A/C not rotated when manual fly (1) Pilot's incapability or system failure when A/P engaged (2) Pitch up too late or too fast (3) Panic (5) Distraction. Unanticipated go-around (2)	15	Not satisfy the go-around climbing rate /Speed up too much (2) Close to TERR (1) A/C did not climb (3) Over speed or under speed (1) No go around pitch (3) Wrong attitude (3) Stall (2)	15
Task execution incomplete	Not enough pitch (3) Under/over rotate or rotate at an improper pitch attitude for go around (1) PF's negligence (2) Did not follow FD pitch (1) Failed to trim to prevent excessive pitch up /failed to trim to reduce forward pressure (2) Distraction. Unanticipated go-around (2)	11	Not enough climb rate or speed too high (2) Not satisfy the go-around climbing rate (2) Climb gradient not enough or lose altitude (1) A/C over pitch which increase pilot's workload (2) over speed or under speed (1) No go around pitch (1) Wrong attitude (2)	11
Task executed too late	PF's negligence (2) Late rotate when go around thrust set (1) Rotate to proper pitch too slowly (5) Panic (3) Pilot's control input later than pitch change because thrust advanced (2)	13	Not enough climb rate (1) Speed up too much (3) Close to TERR (1) A/C continue to sink (2) Affect go-around performance (2) Wrong attitude (4)	13

Table 4: The Qualitative Data Containing the Descriptions and Consequences of the Error for Sub-Task "Rotate to Proper Pitch Attitude" When Performing a Go-Around

be considered for revision (see example given in Table 3). As an example, the qualitative data relevant to the descriptions and consequences of failing to perform properly the task step relating to task 1.3.2 "Rotate to proper pitch attitude" (which was assessed as a "fail") can be found in Table 4.

Many of the errors observed during the go-around show an interaction between procedures and the design of the flight deck. They are not simply the product or either poor design or inadequate SOPs alone. For example, the responses to Question 8 (see Table 2) suggested that on many occasions the thrust levers were not advanced manually when the autothrottles became inoperative. There could be several reasons for this. For example, when a pilot decides to go-around, the first step is to press the TO/GA switches that will activate the correct mode of the autothrust system. However, to control thrust manually, pilots need to press the autothrust disengage switches. Since the TO/GA switches and autothrust disengage switches are next to one another, pilots may accidentally press the wrong switch, which would cause the thrust levers not to advance during the go-around. The following are some related incidents related to the sub-task of "Press TO/GA Switches," (1) Pilot retried to push the TO/GA switch immediately, aircraft continued the go-around operation; (2) Pilot failed to press TO/GA switch, aircraft touched down on the runway due to no go-around thrust and cause hard landing incident; (3) Aircraft became unstable during approach due to unsuccessful go-around. Aircraft went into incorrect pitch attitude, either below normal path or climb to high pitch angle attitude; (4) Flight director (F/D) did not display go-around pitch because of autoflight display system (AFDS) was not triggered; it wouldn't provide correct pitch guidance because pitch mode annunciation did not change to go-around mode. However, the error data also show a failure to follow the required procedures in this instance in Question 23 ("failed to check go-around thrust setting"), which should pick up the failure of the thrust levers to advance to the appropriate setting. Such confusion of system interface components is not new. Chapanis (1999) recalls his work in the early 1940s where he investigating the problem of pilots and co-pilots retracting the landing gear instead of the landing flaps after landing in the Boeing B-17. His investigations revealed that the toggle switches for the gear and the flaps were both identical and next to each other. He proposed coding solutions to the problem: separate the switches (spatial coding) and/or shape the switches to represent the part they control (shape coding) enabling the pilot to tell either by looking at or touching the switch what function it controlled. This was particularly important especially in a stressful situation (for example, after the stresses of a combat mission, or in this case, when performing a go-around).

Even experienced, well-trained and rested pilots using a well-designed flightdeck interface will make errors in certain situations. As a result, CS 25.1302 requires that "to the extent practicable, the installed equipment must enable the flight crew to manage errors resulting from flight crew interaction with the equipment that can be reasonably expected in service, assuming flight crews acting in good faith." To comply with the requirement for error management (which is actually closely associated with procedural design) the flightdeck interfaces are required to meet the following criteria. They should

- enable the flight crew to detect and/or recover from error or
- ensure that effects of flight crew errors on the aeroplane functions or capabilities are evident to the flight crew and continued safe flight and landing is possible or
- discourage flight crew errors by using switch guards, interlocks, confirmation actions, or similar means, or preclude the effects of errors through system logic and/or redundant, robust, or fault-

tolerant system design.

However, many of the procedural errors observed are not direct products of the flightdeck interface. They are mostly errors of omission (a failure to do something). As examples, see Table 2, questions 5, 9, 15, 23, 30, etc. Some of these errors in the execution of the SOPs could be mitigated by changes to the aircraft's interfaces and warning systems (and indeed some are, for example, a speed warning on the landing gear position—question 30, better interface design—question 39, better mode indication—question 46). These all address the first bullet point in the previous list, enabling the crew to detect or recover from error. However, many of the errors listed in Table 2 would not be mitigated by better design (for example, questions 48 and 62). Simplifying or redistributing the go-around procedures between the flight crew members may, however, have a beneficial effect as a result of either redistributing workload (allowing more time for other tasks, such as monitoring the flight instruments) or reducing the number of procedural steps each pilot is required to execute (see Reason, 1988).

Both Reason (1990) and Dekker (2001) have proposed that human behavior is governed by the interplay between psychological and situational factors. The opportunities for error are created through a complex interaction between the aircraft flightdeck interfaces, system design, the task, the procedures to be employed, and the operating environment. It is naïve to assume that simply improving one component (such as the flightdeck interfaces) will have a major effect in reducing error by considering it in isolation. With regard to the HET methodology employed (Marshall, Stanton, Young, Salmon, Harris, Demagalski, Waldmann, and Dekker, 2003) prior to this study, it has always been used in a prospective manner to predict design induced error on the flight deck. This study also demonstrates that it can be used in the opposite manner to structure data collection and provide an analysis taxonomy for the retrospective collection of error data. Looking ahead, the HET methodology can also be applied to prospectively test any revised SOPs to assess their error potential prior to instigating them, thereby avoiding the requirement for an error history to develop reevaluation of the revised procedures is possible.

Conclusion

By the use of a scientific HTA approach to evaluate current SOPs design together with error analysis, interface layout, and operating procedures, the flight safety will be enhanced and a user-friendly task environment can be achieved. This research utilized the HET error identification methodology (originally developed to assess design induced error as part of the compliance methodologies under AMC 25.1302) in a retrospective manner to assess error potential in existing SOPs when performing a go-around in a large commercial jet transport aircraft. Pilots committed three basic types of error with a high likelihood of occurrence during this maneuver: "Fail to execute," "Task execution incomplete," and "Task executed too late." Many of these errors were dormant in the design of the procedures or resulted from an interaction between the procedures and some aspects of the flightdeck design. It is hoped that the implementation of new human factors certification standards and analysis of associated procedures using a validated formal error prediction methodology will help to ensure that many of these potential errors will be eliminated in the future. ◆

Acknowledgement

This project is supported by the grant from the National Science Council of Taiwan (NSC 97-3114-P-707-001-Y). The authors would like to express their appreciation to the Aviation Safety Council for providing a financial endowment to carry out this research.

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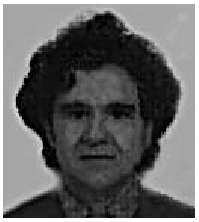
An Analysis of Human Factor Aspects In Post-Maintenance Flight Test

By Capt. Claudio Daniel Caceres, Senior Safety Advisor, Continuous Safety®, Switzerland



Capt. Claudio Caceres has been an aviation consultant since 2007. With almost 1 year of membership at the European Business Aviation Association's (EBAA) FTL Working Group, he has contributed to sustainability of the EBAA's FTL position. Having completed U.S. NTSB training in Washington, D.C., on the fatigue risk management system (FRMS), Caceres has provided valuable information to the working group based on the current scientific evidence. He served 2 years as a flight operations and training PH for an Italian business aviation AOC operator. After that, he supported Sirio Spa, Milan, Italy, by implementing new EU rules and a quality management system. Canceres has more than 20 years' aviation experience, the majority as an airline captain on narrowbody and widebody aircraft. His career includes 10 years as a quality auditor, security manager, and instructor. He also is a part-time aviation security advisor for the Italian CAA ENAC. During his time with ENAC, he was extensively involved in the EU regulatory development process, especially in the field of human factors applied to security. He has also worked with the European Civil Aviation Conference as a certified aviation security auditor. Caceres holds two master degrees from the City University of London, U.K., one in air transport management and one in air safety management. He has completed the Air Accident Investigation Course at Cranfield University in 2003.

Introduction

Although the civil aviation industry has achieved a distinctive excellent safety record, there are still some risky operations, such as test flights after line maintenance, that can be dangerous and need to be performed with extreme care.

These operations are usually performed by a highly skilled staff in an already high-risk environment, with a great number of internal and external hazards sometimes resident in the system.

This justifies the necessity to perform flight tests in order to detect any fault before the aircraft is released to service. This operation tries to avoid that a single undiscovered fault can trigger an undesired state of the aircraft or leads to a bad outcome.

Since a flight test is a process that involves a wide range of professionals from different agencies, with different purposes, the outcome of that attempt should minimize further risks. Errors can be generated as a result of a technical defect or a less-than-optimum human performance during the tasks.

A test flight demands special care and awareness, exceeding the one used in normal line operations. For instance, the line flight crew that normally completes those flights can be easily affected by fatigue, stress, fear or exuberance, as well as improper discipline and lack of continuity. The one ordering the test or collecting the data can request the crew to execute a complex maneuver that is beyond the crew's competence or proficiency.

These flights also involve a wide cross-section of other agencies from the aviation community, which usually are not used to handling flight tests everyday (ground handling agencies, ATC, radar, etc.). Standardizing the procedures of the parties involved represents a positive contribution to the successful completion of an effective, efficient, and safe operation.

Finally, in the findings and recommendations the importance of personnel awareness and the use of agreed-upon written procedures and safety information will be underlined. Accordingly, special briefings and training to ensure that critical phases of these operations are under proper control will be proposed, both technically and from the human factors side.

The research methodology

In the present chapter, the author outlines the research methodology that was used to assess some Italian and European Air Operator Certificate (AOC) operators in dealing with issues related to human factors in post-maintenance flight tests. The actual regulatory framework was analyzed, as well as the approach that the authority has taken with post-maintenance flight tests.

Objective of the survey

The objective of the survey was to analyze the way that AOC operators are actually dealing with human factors aspects in post-maintenance flight tests. According to ICAO, safety is a condition in which the risk of harm or damage is limited to an acceptable level (see Reference 1). That underlines the fact that the outcome from human factors aspects influences the overall risk level of the operation. The author also considered crucial the assessment related to human factor aspects and good safety management practice principles.

The assessment took place through the means of the survey's questionnaire and documental review. This review consisted of gathering and classifying information regarding actual control measures. This sample taken from the industry in form of standard operating procedures (SOPs) tried to identify hazards and associated risks during such activities, including human factors characteristics.

Description of data

The survey's questionnaire consisted of a set of six questions that focused on areas of concern. Policy, human factor aspects, and the risk management in post-maintenance flight tests were taken into account. In particular, the survey's questionnaire was designed to better examine the next six systemic areas:

1. policy.
2. procedure, which includes human factors.
3. identification and tracking of hazards and associated risks.
4. involvement in safety occurrences.
5. development of corrective actions.
6. monitoring the effectiveness of the correcting actions.

Since the survey requested reporting non-compliance events and follow-up activities, which are sensitive issues, the author, therefore, let respondents answer via e-mail, mail, or fax. The author guaranteed that only deidentified data would be included in the present work to protect the participants from the concern of self-incrimination as well as undesirable negative consequences for their organizations. The present project hopes to assess the system as a whole, not the individuals or their organizations.

In order to get a wider view and a better understanding of the topic, the author also performed a documental control. The control consisted in the review of the Jar-OPS 1 format Operations Manual Part A, Chapter 8.7, "Non Revenue Flights, Flight Test" as the component of the SOPs of some European AOC holders operators. Specifically, the review of such documentation was to try to research if the human factor aspects during post-maintenance flight test were considered in the official documentation. Since the result of the recognition that human action does not occur in a vacuum but in a context of organizational and technological factors (see Reference 2), the author also considered as fundamental analyzing hazard identification as well as risk management and risk mitigation aspects included in those documents.

Target population

The author sent the survey's questionnaire to the members of the Italian Flight Safety Committee (IFSC). Some other Italian independent AOC holder operators also received the survey's questionnaire. However, the author also reviewed operations documentation corresponding to some European AOC operators and other Italian AOC operators. The IFSC was established in 1999. It represents the Italian Flight Safety Society in tune with the similar model developed in the United Kingdom with the United Kingdom Flight Safety Committee and by the Flight Safety Foundation in the United States. It objectives include the development of a safety culture to achieve the new safety standards required to face the increasing traffic growth. According to its website (see Reference 3), the IFSC's members include about 20 AOC operators, one rotary-wing operator, the authority (ENAC), the Italian air traffic control service provider (ENAV), two aircraft manufacturers (one fixed wing and one rotary wing), the Italian carrier association, four airport operators, and one handling agent.

The industry practitioners that received the survey's questionnaire were mainly flight safety managers, quality managers, and post holders flight operations and post holders CAMO.

The document control reviews Chapter 8.7 of the following AOC operators:

1. No. 3 European carrier operators having more than 100 narrowbody and widebody aircrafts.
2. No. 4 European carrier operators having fewer than 20 aircraft.
3. No. 3 European Business jet AOC operators having fewer than 20 jet aircraft.

Pilot survey process

The survey's questionnaire was sent to the IFSC via e-mail, and it was presented by the IFSC's coordinator to the IFSC's members on Nov. 30, 2007. The initial closing date set by the author was Dec. 15, 2007. However, the proximity with the end of the year and the winter break made it difficult for the participants to meet that deadline. The author decided to extend the period until the Jan. 31, 2008. By Jan. 8, 2008, the author had sent 57 individual e-mails to the IFSC member, asking them to send back the questionnaire. This motivated the participants to respond and more questionnaires were returned.

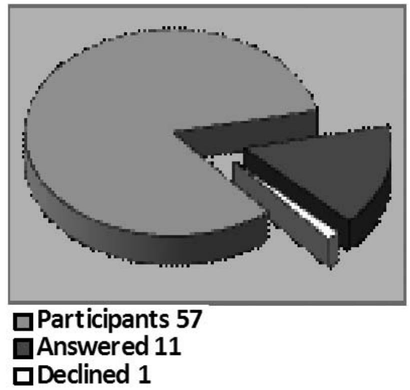


Figure 1. Analysis of the survey's data.

The survey's report

The filled-in questionnaires that the author received were first deidentified, as per the current disclaimer policy, and then the operators were assigned letters from A to Z. There was one operator that answered in an informal way, without using the questionnaire. Another operator answered stating that he was not able to provide such data arguing that the dissemination of data in the way requested was not allowed by unions, company policy, or Italian law.

Analysis of survey's data

The total number of participants invited to participate were about 57 Italian AOC operators. The total numbers of answers are divided in the following way:

The metrics about the answered questionnaires are as follows:

Question Number	Yes	No	N/A
No. 1 (Policy for flight tests)	6 (75%)	2 (25%)	0
No. 2 (If it includes Human Factors aspects)	3 (37.5%)	5 (62.5%)	0
No. 3 (Identification of risks)	4 (50%)	4 (50%)	0
No. 4 (Involvement in Safety occurrences)	4 (50%)	4 (50%)	0
No. 5 (Implementation of corrective action)	4 (50%)	3 (37.5%)	1
No. 6 (Monitoring of effectiveness of the corrective actions)	5 (62.5%)	3 (37.5%)	1

The analysis of the documental control

Regarding the regulatory framework, the actual regulation for AOC European Union member states operators in the area of "operations" is JAR-OPS 1/3. Amendment 7 is the current issue required by ENAC to Italians AOC holders. JAR-OPS 1/3 remained valid until July 15, 2008. After that date, Regulation EU No. 8/2008 implementing the new EU-OPS rules to EU operators became effective. Both requirements and regulations impose in their Appendix 1 to JAR-OPS 1.1045 (or OPS 1.1045 in the second case) "Operations Manuals Contents," the structure and contents of the mandatory operating documentation. Appendix 1 to JAR-OPS/OPS 1.1045 in Chapter 8.7 requires the "procedures and limitations" for "non-revenue flights." Such procedures and limitations specifically must address, in a form

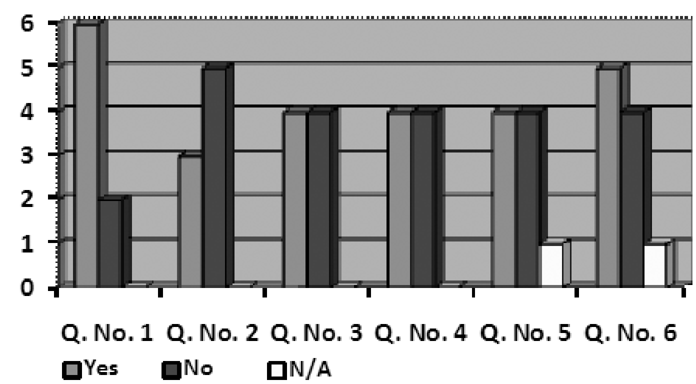


Figure 2. Analysis of the survey's data by question numbers.

GOOD PRACTICES FOR FLIGHT TEST	ITALIAN OPERATORS					EU OPERATORS				
	ITA 1	ITA 2	ITA 3	ITA 4	ITA 5	EU 1	EU 2	EU 3	EU 4	EU 5
1. Definition	-	-	-	-	√	-	√	√	√	√
2. Policy	√	-	-	-	√	-	√	√	√	√
3. Definition of the Owner of the Process	-	-	√	-	√	√	√	-	V	√
4. Hazard Identification	-	-	-	-	-	-	-	-	-	-
5. Risk Assessment	-	-	-	-	-	-	-	-	-	-
6. Flight Planning and ATC Coordination	-	-	√	-	√	-	√	-	-	-
7. MEL Standard Requirement	√	-	-	-	-	-	-	-	-	-
8. Dedicated Briefing (including HF)	-	-	-	-	-	-	-	-	-	-
9. Dedicated Briefing with PH CAMO	√	√	√	√	√	√	√	√	√	√
10. Categorization	-	-	√	-	√	-	√	-	-	√
11. Precatuions and Procedures	-	-	-	-	√	-	-	-	-	√
12. Procedure	√	-	-	-	√	-	√	-	-	√
13. Passengers Limitations	√	√	√	√	√	-	√	√	√	√
14. Cabin Safety Procedures	-	-	-	-	√	-	√	-	-	√
15. Limitations	√	-	-	-	√	-	√	-	-	√
16. Customer Test Flight	-	-	-	-	√	-	√	√	-	√
17. Insurance Coverage	-	-	-	-	-	-	√	-	-	-
18. Weather Restriction (i.e., Daytime)	-	-	√	-	√	-	√	√	-	√
19. Safety Pilot/Engineer	-	√	√	√	√	-	√	√	√	√
20. Taxi test Policy	-	-	√	-	√	-	√	-	-	√
21. Engine Run Policy	-	-	-	-	√	-	√	-	-	√
22. Dedicated Flight Crew Rostering	-	-	-	-	√	-	√	√	√	√
23. Experience Staff Only Requirement	√	√	√	√	√	-	√	-	-	-
24. Flight Test Manual	-	-	-	-	√	-	-	-	-	-
25. Dedicated AFM Charter	-	-	-	-	√	-	-	-	-	-

Figure 3. Evaluation of 10 Italian and European AOC operators.

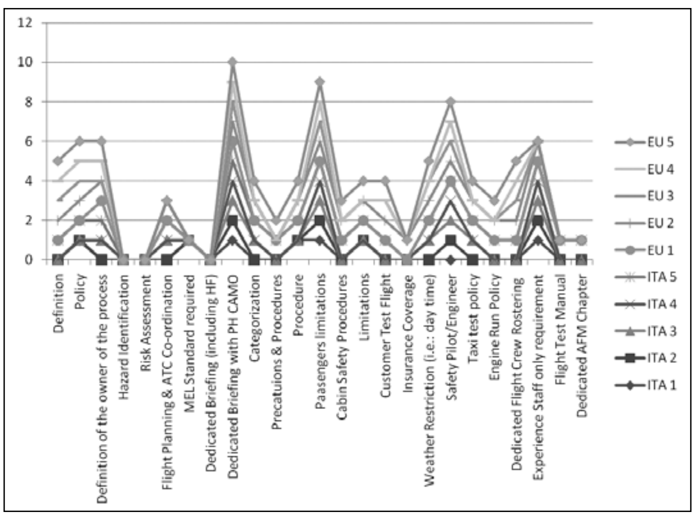


Figure 4. Graphic presentation of the evaluation of 10 Italian and European AOC operators.

of control measures, issues related to

a. training flights,
b. flight tests,
c. aircraft delivery flights,
d. ferry flights due to maintenance procedures,
e. demonstration Flights, and
f. positioning flights.

The importance to establish a policy and procedures beyond compliance

The operations manuals are part of the company's standard operating procedures. Such documents are subject to the approval of the authority. They represent the statement and even the way the operator conducts its operations. The review of Chapter 8.7 represented for the author another key opportunity to get research information. The practical concern for safety is usually driven by events that have happened, either in one's own company or in the industry (see Reference 4).

Conversely, in a proactive point of view, the author decided to review the procedures in place made by the authority. The added value of the proper procedure's effectiveness is well beyond a mere regulatory compliance, and it is worth keeping them updated integrating input from occurrences that happened to other operators. The author focused on test flights and reviewed the procedures and the limitations of eight operations manuals, Part A, Chapter 8.7, belonging to European and Italians AOC operators. Chapter 8.7 should clearly define safe flight conditions and meet technical objectives.

Documentation analysis results

The author reviewed the part dedicated to flight tests from 10 operations manuals that belong to Italian AOC holder operators and European Union member AOC holder operators. From the data, the author produced a grid that includes a selection of items that can represent the industry's best safety practices control measures. To that list, the author added the topics concerning the recommendations issued by ICAO regarding safety management: hazard identification, risk assessment, and a dedicated safety briefing, including human factor aspects and self-evaluation limitations. The findings that the author collected can be summarized as follows:

General background about different definitions related to flight testing of aircrafts

In order to better clarify the topic, the author provides some specific definitions about flight tests.

Flight test: A required means of establishing compliance with certification requirements for new aircraft and changes to aircraft.

Types of flight testing: Check flights or inflight surveys can be carried out periodically on in-service aircraft as one of the processes to ensure that an aircraft continues to comply with the applicable airworthiness requirements.

Maintenance check flights: May be carried out following a maintenance activity on an aircraft to provide reassurance of handling characteristics, performance, or to establish the correct functioning of a system that cannot be fully established during ground testing.

Permit to fly: Special document issued by EASA or the NAA or by the state of registry to an aircraft that temporally lost its C of A and allows the owner or the operator to make a ferry flight to the next approved repair station or to perform a flight test limited to the maneuver exclusively stated in that document in the flight test schedule (FTS) or in the aircraft flight manual (AFM), whichever is limiting.

Findings and recommendations

The author acknowledges that AOC holder operators in Italy and in Europe have systems in place characterized by different grades of maturity. Operators' experience, knowledge, organizational culture, and size, as well as available resources, influence the grade of system's maturity. The actual regulation requires that operators should be able to deliver a similar safety standard through a system "based on compliance with, and adequacy of, procedures required to ensure safe operational practices and airworthy aeroplanes." (See Reference 5.) Regulatory compliance in post-maintenance flight tests is not enough, unless the system encompasses the human limitations and develops strategies on how to address elements related to aviation human factors. This will permit the system to effectively manage the related operational risks. A documented and auditable approach allows continuous improvement of procedures, which is also able to integrate the feedback from operations and industry wise. Operators have to demonstrate the airworthiness compliance in their maintenance programs. That includes flight tests, inflight surveys or demonstration flights. It is up to the operators to set up control measures specifically related to human factors during post-maintenance operations. Ignoring these underlying safety hazards could pave the way for an increase in the number of more serious occurrences (see Reference 6.) The collection of data gathered from the survey's questionnaire and from the official documentation reviewed made evident some systemic inconsistencies in the following key areas:

1. Clear identification of the owner of the process regarding flight test.
2. The risk assessment decision-making process and communication system to flight crew.
3. The establishment of standardized supportive briefing guidance material that includes HF best practices.
4. Over-reliance on experienced captains (or TRE/TRE) instead of the concept of flight crew.
5. Lack of dedicated flight tests guidelines and/or training.
6. List of authorized flight crew to perform flight tests.

Presentation of findings: The owner of the process post-maintenance flight tests

It was observed that the post-maintenance flight tests process owner was not clearly identified, not included in the documentation. This can lead to people not being aware of their role in such a position. In other cases, the flight operations post holder required the CAMO post holder to answer on behalf the organization. Only one safety manager answered the survey's questionnaire, however using an informal e-mail format.

The identification of who controls the process enhances the level of standardization. A standardized process improves the possibility of replication, planning capability, the quality of data collection, and leads to a safe execution of the flight tests, as well as proper debriefing and data confirmation.

It is crucial that the operations manager is the owner of the process and develops a correct flight planning, considering all relevant aspects that can influence the output, including human factors. The maintenance sector should simply ask for certain data that flight operations should gather during the flight tests.

The person in control should be clearly stated in the flight test policy and included in both the operations manual and the continuous airworthiness maintenance exposition (CAME). The coordinator should be a commander from the Flight Operations Department and had the role of coordinator In some cases, it was observed that the flight operations post holder was filling the role; however, without clear statement concerning responsibilities. Usually the flight operations post holder is an experienced person approved by the authority. His position is not enough as a risk control measure. Commercial pressures, complex environments, and/or organizational cultures can decrease the objectivity of the assessment related with the operational hazards and its associated risks. The support of a flight safety review board (FSRB) that encompass at least the post holder CAMO, the safety manager, and the quality manager could assist the overall organization in delivering a more effective and efficient solution for post-maintenance flight tests. Finally, the establishment and implementation of the role and responsibility of the "flight test coordinator" per the Flight Safety Review Board (FSRB) is important to permit the system to define safe flight conditions and meet technical objectives, in an efficient and effective manner.

The post-maintenance flight tests process

The purpose of airworthiness check flights is to ensure that the aircraft's flight characteristics and its functioning in flight do not differ significantly from the normal characteristics for the type and to check the flight performance against the appropriate sections of the flight manual (see Reference 7).

A clear definition of the role and responsibilities of the owner of the process should enhance the planning process, especially in the following critical areas:

a. Definition of the flight test schedules approved by the NAA or by the manufacturer.

b. Definition of the safety considerations and control measures for such a mission (hazard identification and risk assessment).

c. Since human action does not occur in a vacuum but in a context of organizational and technological factors, this must be taken into consideration.

The design of the post-maintenance flight test process

Drawing the process of a post-maintenance flight test can be very helpful in identifying and communicating the critical areas of concern. Since improvisation increases the risk, the process above describes the time necessary to make an effective planning of the flight test. Good safety management practices from the organization is required to identify areas of concern and associated risks.

Areas such as pre-flight inspection, aircraft acceptance, ramp safety, and taxiing in complex environments that are not quite famil-

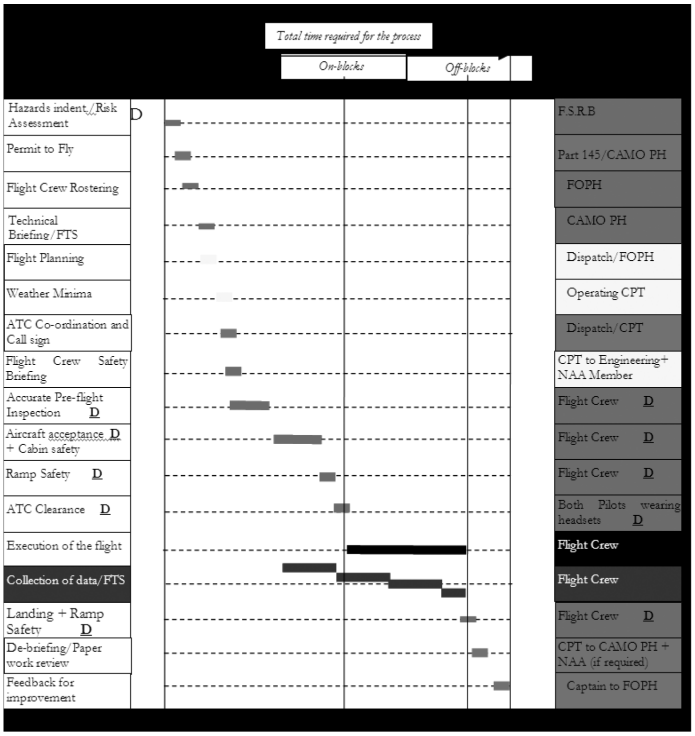


Figure 5. A generic example of a post-maintenance flight test process, which shows where critical areas are and where double-checks are requested.

iar to the flight crew can expose the operation to an unacceptable risk level. The use of colors or effective symbols, like the ones already used in maintenance on task cards, to specify a double-check (i.e., "D") could draw the attention of the staff regarding specific critical steps that require double-control check.

Pilots conducting check flights

Pilot acceptance, criteria, and procedures for conducting check flights should be included in the continuing airworthiness management exposition in accordance with Regulation (EC) 2042, Part M.A. 704 where applicable (see Reference 8).

Dedicated post-maintenance flight test procedure considerations

In the following paragraph, the key items for successful flight test activities will be discussed. A chase aircraft normally is not required for post-maintenance flight test. Sometimes searching for failure during maintenance activities requires installing cameras outside of the aircraft to record system performance. However, this shall not be the source of crew distraction. Digital cameras set in high resolution can be very useful in data gathering instead of writing on the FTS, which sometimes can be very challenging in flight.

Planning a post-maintenance flight test

Planning requires the use of the approved flight test plans or manufacturer's flight test schedule, prepared by the CAMO post holder in coordination with the FOPH. Manufacturer's or CAME instructions should be observed at all times. Flight tests plans or flight test schedules should be prepared by the CAMO post holder in coordination with the relevant authority and the Part 145 that completed the work and was approved by the PHFO. A permit to fly is required prior to starting the test, as per Regulation (CE) No. 375/2007 (see Reference 9).

Test maneuvers

In order to facilitate the flight crew's awareness, the organization should provide in-depth explanations about the three areas of operations and its dedicated information (see Chart A).

The flight crew should operate outside of the operator's SOPs, strictly limited to the time required to complete the flight test requirement. The flight crew briefings should cover all scheduled maneuvers and its related safety measures. Any other contingency recover manoeuvres should be reviewed. Members of the authority shall be briefed in advance, that, condition permitting, only discussed

Normal	SOPs: Familiar.
Close to aircraft limitations	AFM: Self familiarization required.
Beyond aircraft limitations	Special manufacturer's flight test chapter in the AFM and in-depth briefing training is required.

Chart A

CRITICAL STEPS/PHASE	JUSTIFICATION
Hazard identification/risk assessment	Planning a post-maintenance flight test with instrument meteorological conditions or extreme weather like ice or wind can expose the operation to unacceptable risk.
Flight crew composition	Experienced commanders or TRE/TRI are exposed to any possible human impairment factors. The use of a "homogenous" flight crew concept makes redundant the flight crew composition.
Technical briefing	A clear statement of the objectives of the test clears up any confusion about the mission's objectives for the flight crew, engineering, and the Authority when on board. The flight crew is not always familiar with FTS layout and technical issues. Avoid adding items not briefed on the ground. Any member of the crew is entitled to announce "stop" of the test.
Pre-flight inspection	Accurate in-depth pre-flight inspection can detect maintenance omissions as well as wrong panel settings.
Aircraft acceptance	The decision to continue with the process when further MEL items emerge during acceptance, such as fuel leak, partially faulty instruments, or other non-compliant items that can further increase the risk and the oper ating pressure on the flight crew.
Ramp safety	Often maintenance areas are not well equipped, marked, or familiar to the Flight Crew. During taxiing, special attention on crew orientation is required when reaching the runway in use.
ATC clearance	The flight crew might not be familiar with the special phraseology or ATC clearances used during flight tests. A mistake can create traffic conflict or crew disorientation.
Landing plus ramp safety	Following demanding tasks, in this phase, the flight crew may become less focused or distracted (complacency might arise), while taxiing in unfamiliar or complex areas.

Figure 6. Explanation of critical phases of the post-maintenance flight test process.

and agreed-upon maneuvers are to be completed in flight and only conditions permitting. Any unsafe/uncontrolled exceedance will require the crew to abort the mission, to land as soon as possible, and to participate in a debriefing, and inspect the aircraft. Any flightcrew member can announce “stop” in case he/she notices any abnormal situation that might jeopardize flight safety.

Identification of hazards

The basic premise is to identify test-specific hazards so that controls can be placed on the flight test activity to minimize the probability of hazards occurring. Hazard identification is a key activity during post-maintenance flight test planning. Flight test schedules demonstrate system performance in an already certified system. The flight crew, familiar with the aircraft’s system and its intended use, identifies most of the hazards. Careful evaluation of the flight test schedule in the operational context should be considered to address its related flight test hazards. These hazards are highlighted in the safety plan that should be issued by the FSRB. It consists in combination with an executive summary and a staff summary sheet. Thus, risk management is at the core of the flight test plan approval process. A complete safety plan documents both the flight test hazards and the risk mitigation plan.

An approach to hazard identification can be summarized as follows:

1. The hazard (anything that could lead to a mishap. It must be test specific and not a generic hazard associated with generally flying airplanes).
2. The causes of the hazard (anything that could lead to the presence of the hazard).
3. The effect of the hazard (the mishap you are trying to prevent: death, loss of aircraft, major damage, etc.).
4. Minimizing procedures that address the specific causes of the hazard to prevent its occurrence (breaks the link between the causes and the hazard).
5. Corrective actions that document what to do if the hazard occurs to prevent it from becoming a mishap (breaks the link between the hazard and the effect or mishap).
6. Remarks that document additional applicable information about the hazard.

Hazard classification and protocol should be performed.

Analysis of the effectiveness of the control measures

The safety plan, which includes the flight test plan, should be supported by an independent safety review and based, for example on a qualitative risk assessment performed with the BowTieXP© methodology. The safety review board (SRB) should be chaired by the FOPH, and it should be composed of at least the post holder CAMO, the safety manager, and the quality manager. This team reviews the flight test plan and the safety plan, identifies additional hazards, recommends additional risk mitigation (or the elimination of risk mitigation that will be counterproductive or unnecessary) and finally assesses the overall risk of the post-maintenance flight test.

Risk assessment and safety planning

The final risk assessment is the responsibility of the FOPH. The Board assesses the overall risk of the flight test based upon the identified risk, risk mitigation efforts, and potential for unknown risks.

The assigned risk level (low, medium, or high) determines the level of supervision required to approve the flight test plan. During risk management and assessment, the Flight Safety Review Board members should make a subjective decision of their assessment. This should also remind the staff involved in the operations and Flight Safety Review Board members that although a minor improvement in the safety plan may not change the assessed “severity,” “probability” or “risk,” it may still reduce the actual risk.

The use of the flight test schedule

The ICAO airworthiness manual, Volume 1, states the purpose of post-maintenance flight test or check flights. It also states that the objectives of such flights are to ensure that the aircraft’s flight characteristics and its functioning in flight do not differ significantly from the normal characteristics for the type and to check the flight performance against the appropriate sections of the flight manual (see Reference 10). ICAO recommends the above operation through the application of flight test Schedules approved by the authority. However, since there is an ongoing transition from NAA to EASA regarding EASA-registered aircraft, the national aviation authorities within the 27 European member states limit the requirements to non-EASA-registered aircraft. The EASA introduced a non-expiring certificate of airworthiness for EASA registered aircrafts (airworthiness review certificate [ARS]). However, the aircraft operator has to review the airworthiness the aircraft through a maintenance plan. In the future, the owners or aircraft operators will establish a need to carry out periodic check flights as part of their own airworthiness assurance process to ensure that their check flight schedules and procedures are developed in accordance with current best practices. The support of the aircraft manufacturer or the NAA Flight Department will be crucial for advice on content and safety procedures, which includes human factor aspects. The EASA regulations also place obligations upon NAAs as the designated competent authorities for the European Union member states in respect to aircraft continuing airworthiness monitoring. This requires the NAAs to monitor the airworthiness status of the fleet of aircraft on its registry and may include inflight surveys as one element.

Objectives and contents of the flight test schedules (FTS) and hints of human factors

The FTS is a crucial tool, and its objectives are to assist the operator in confirming the following data:

a. Handling characteristics are satisfactory and typical of the type.
b. Climb performance equals or exceeds the scheduled data (see Chart B).
Note: Data are necessary in order to assess any future deterioration of performance in service.
c. The aircraft and its equipment function satisfactorily and the aircraft continues to comply with its type design standard.

From the human factor point of view, it is wise to consider that individuals, in confined spaces, will use the above flight test schedules. The

1. Takeoff	Consider stop T.O., busy areas, high workload
2. Climb	Busy areas plus navigation
3. Cruise	Navigation accuracy
4. Flight at maximum speed	Risk of high speed Stall
5. Flight at minimum speed	Risk of low speed Stall
6. Descent	Descent preparation plus approach briefing
7. Landing and	Busy areas, high workload, review go-around
8. Hover maneuvers for helicopters	Proximity to ground

Chart B

FINDING	ACTION
Define clear policy on FT	O.M. Part A, 8.7 – Policy
Define clear FT Procedures	O.M. Part A, 8.7 – Procedures
Define a FT pilot qualification process	O.M. Part D – Qualification & Training
Define a list of pilots (EASA/M.A.706)	CAME – FT Chapter
Define clear FT Practices	O.M. Part A, 8.7 – Mandatory briefing
Consider HF aspects of FT	O.M. Part A, 8,7 – HF aspects during FT
Review Instructions to FT crew	CAME – Flight Test Schedule (FTS)
Define possible FT fleet wise	CAME – FT Requirement
Review & up-to-date risk assessment	F.S.R.B.: FOPH, CAMO PH, QM, SM
Define recurrent training	O.M. Part D – FT Recurrent training

Figure 7. Documentation contents

quality of data will depend on readability, spaces for the collection of data, type of fonts as well as the size and color of the paper sheet.

The U.K. CAA recommends that the schedules should cover the following:

a. Handling tests, including the effectiveness of primary controls and trimmers, with specific direction (see note) to evaluate the characteristics during the following phases of flight.

b. Performance tests

1. Simple, free air pressure rate-of-climb measurements under known and predicted configurations and conditions, and

2. Measurement of low-speed warnings and, if applicable, stall speeds.

c. Tests to check functioning of the aircraft equipment in flight and safe, recoverable functioning of back-up systems e.g., emergency gear lowering, use of alternate braking systems. Note that controls, systems, and equipment that are used regularly may be considered, for the purpose of the schedule, to have been checked on the basis of normal usage.

Schedules for required check flights for EASA and non-EASA aircraft should be available for most aircraft types (and variants thereof) above 5,700 kg MAUW. However, for certain categories of airplanes below 5700kg MAUW, there are generic schedules that can be used for a range of airplane types (NAA responsibility).

Post-maintenance flight tests results

After each check flight, the flight crew that conducted the flight test due to maintenance should complete the post-flight certificate in coordination with the CAMO post holder. The flight crew should list all the defects found during the flight. This, together with the completed flight test schedule, comprises the check flight report. Each defect should be classified according to its impact on safety. Feedback should be given to the PHFO, especially in the field of human Factors. This will allow the system to strive for continuous improvement and review of the process. The information contained in the feedback should be integrated into the training process regarding flight tests. This will avoid recurrence of non-compliance events and improve safety.

Conclusion

The post-maintenance flight test is a non-recurrent activity in which routine does not take place. The organization must give the flight crew and the staff involved with clear instructions. The natural documentation should be at least included in the following company documentation:

The above documentation must be easy to read, eliminating ambiguity and designed in the form of the following representation:

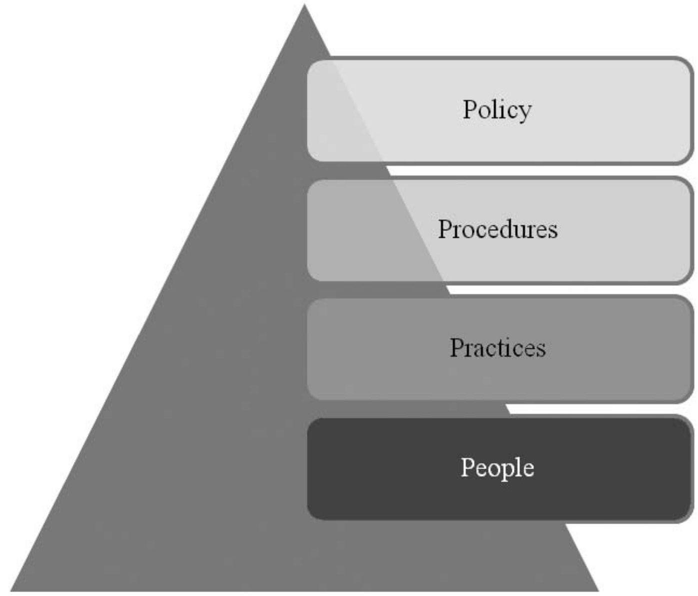


Figure 8. The policy, procedures, practices, and people and its relationship with the safety culture (see Reference 11).

The policy and the procedures are the general instructions on how the staff must perform the tasks. The practices and the people represent the real way that sharp end staff is conducting the tasks. The gap between the policy and the procedures is related with increased risk. The closer the gap, the less the likelihood of noncompliance. Feedback and procedure update is needed to keep the system as safe as it should be.

Another key factor resides in a task prioritization and proper workload management during the whole process. A well-planned mission, supported by an adequate briefing with clear declared mission objectives is the basic stimulus to be certain about what to test. ◆

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Findings of Using Human Factors Analysis and Classification System (HFACS) as a Tool for Human Factors Investigation

By Yung-An Cheng, Thomas Wang, Jenn-Yuan Liu, Chi-liang Yang, and Wen-Chin Li

Thomas Wang *is currently the director of the Flight Safety Division, Aviation Safety Council, Taiwan, ROC. He is a former airline pilot who flew the Airbus A300. Thomas joined the ASC as an aviation safety investigator in 2000, primarily working on the flight operation and human factors investigation.*

Photo not available

Yung-An Cheng *is currently an engineer for the Flight Safety Division, Aviation Safety Council, Taiwan, ROC. Cheng joined the ASC in 2001. His primary role is to investigate aerodrome and organizational factors. He is also handling the voluntary safety reporting system of the ASC.*

Photo not available

Jenn-Yuan Liu *is currently an engineer for the Flight Safety Division, Aviation Safety Council, Taiwan, ROC. She used to be an analyst for the Flight Standards Division, Civil Aeronautic Administration. Liu joined the ASC in 2001, primarily working on survival factors issue during investigations.*

Photo not available

Chi-Liang Yang *is currently an associate engineer for the Flight Safety Division, Aviation Safety Council, Taiwan, ROC. He joined the ASC in 2003. In addition to participating in routine investigations, he is also working on the voluntary safety reporting system.*

Photo not available

Dr. Wen-Chin Li *is the head of the Graduate School of Psychology, National Defense University, Republic of China, and a Visiting Fellow in the Department of Systems Engineering and Human Factors, Cranfield University, United Kingdom. He is an aviation human factors specialist for the European Association of Aviation Psychology and a registered member of the Ergonomics Society (MErgS). He and his co-authors won the prize for the best paper of the 2007 ISASI seminar.*

Background

All kinds of data indicate that various human errors are involved in the majority of aviation occurrences (see Reference 1). According to Boeing's annual statistical summary, about 70% of aviation occurrences were related to the actions of flight crews, maintenance personnel, air traffic controllers, aircraft system engineers, or others. It is obvious that investigation agencies need to put more emphasis on human factors (HF) in aviation occurrence investigations to explain how and why the occurrences occurred.

Though the majority of aviation occurrence investigators are specialists in technique and operation, only a minority of them specialize in HF. In some cases in which the tangible technical evidence was limited, they would enlist investigators who have knowledge and skill in dealing with HF issues. The ICAO Human Factors Digest (see Reference 2) suggests that providing intensive HF training to investigators will give them the essential knowledge and skill. Developing a uniform approach ton HF investigations is a universal goal of each investigation agency. However, the progress is relatively slow.

The Aviation Safety Council (ASC) is an independent government agency responsible for civil aviation occurrence investigations in Taiwan. Since May 1998, the ASC has conducted 63 investigations and issued 420 safety recommendations. However, compared to the NTSB, the ATSB, the TSB, and other well-developed occurrence investigation agencies in the world, the ASC is still a young organization building up its investigation capacities, especially in HF aspects.

Current practices of HF investigation

To understand the current practices of HF investigation, a research team from the Boeing Company (see Reference 3) surveyed 12 aviation occurrence investigation agencies in 2006 and documented their approaches to human performance (HP) issues in investigations. In the survey, one inquiry was regarding the number of investigators or staff who have been formally trained as HP experts (they have M.S., M.A., or Ph.D. degrees in HF-related fields), and the responses were considerably varied. In contrast to five agencies that had no investigator trained in the HF field, two agencies had 10 personnel, and another two agencies had 6 personnel trained in HF field. Those agencies that have no HF expertise in house often hire consultants who have that expertise.

The survey also inquired about the types of HP training provided to the investigators. For four agencies, the HF training is a part of broader investigation courses. Another four agencies sent each of their investigators to a dedicated HF course. For the remaining four agencies, only a few investigators may receive some HF trainings.

Another issue concerned in the survey was the procedures that agencies provided to guide the HP investigation. The results indicated that some of the 12 agencies had no such document at all; meanwhile some of the agencies had an investigation manual or general guideline that aided them in investigating HP issues. The survey revealed that the more HF expertise the agencies had, the more HF investigation guidance the agencies can develop. Since agencies with less HF expertise seem unable to develop the HF investigation guidance by themselves, acquiring it from out-sourcing became a potential solution. Unfortunately, practical HF investigation documents are very rare in the aviation community.

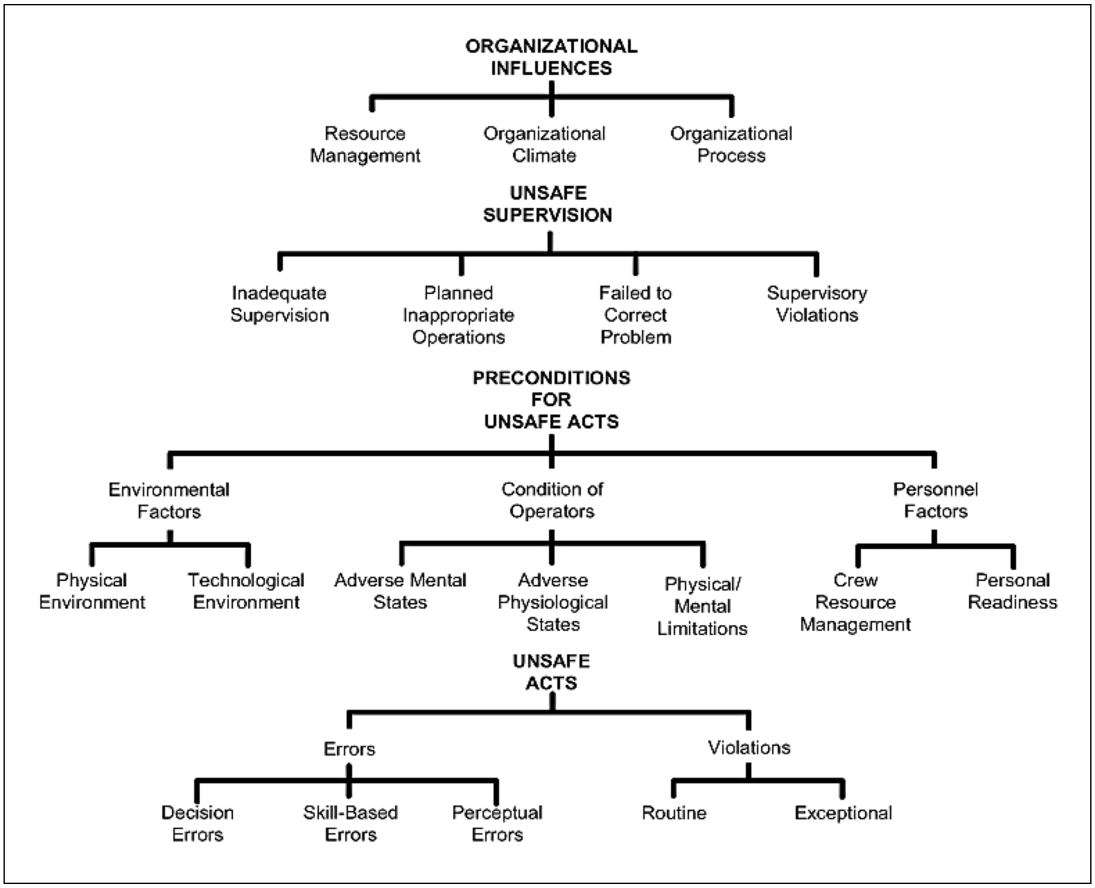

Figure 1. The HFACS framework (adopted from Shappell and Wiegmann, 2007).

Human Factors Analysis and Classification System

Human Factors Analysis and Classification System (see References 4-6) is a generic human error framework originally developed for U.S. military aviation as a tool for the investigation and analysis of human factors aspects of accidents. It is based upon Reason's (1990) model of human error. In this model, the active failures are associated with the performance of front-line operators in a complex system. Latent failures that lie dormant within the system for a period of time are triggered when combined with other local factors to breach the system's defenses. Active failures of operators have a direct impact on safety. Latent failures in the system are spawned in the upper levels of the organization and are related to management and regulatory structures. Wiegmann and Shappell claim that the HFACS framework bridges the gap between theory and practice by providing safety professionals with a theoretically based tool for identifying and classifying the human errors in aviation occurrences. Given that the system focuses on both latent and active failures and their inter-relationships, it facilitates the identification of underlying causes of human error.

HFACS (see References 6-8) addresses human errors at four levels, each of which influences the next level. The framework is described diagrammatically in Figure 1. The first level of HFACS classifies events under the general heading of "unsafe acts of operators" most closely tied to the accident. Failures at this level can be classified into two categories, errors and violations. The second level of HFACS concerns "preconditions for unsafe acts." It addresses the substandard conditions of operators and the substandard practices that they perform within the causal sequence of events. The third level is "unsafe supervision." This level traces the causal chain of events producing unsafe acts up to the level of the front-line supervisors. The highest level, the fourth level of HFACS, is "organizational influences." It describes the contributions of fallible decisions in upper levels of management that directly affect supervisory practices, as well as the conditions and actions of front-line operators.

Applications of HFACS

HFACS was originally designed and developed for U.S. military aviation operations. Its applicability had also been demonstrated regarding the analysis of accidents in U.S. commercial aviation and general aviation (see References 9-10). Li and Harris (see Reference 11) demonstrated that the HFACS framework has a high degree of inter-rater reliability and is applicable regarding analysis of accidents in a different cultural context. In recent years, the framework has also successfully been used and proven its applicability to the analysis on Taiwanese military and commercial aviation accidents (see References 11-12).

In 2007, the Australian Transport Safety Bureau (ATSB) conducted a study on "Human factors analysis of Australian aviation accidents and comparison with the United States" to systematically analyze the types of human error occurring in Australian civil aviation accidents and compare results against a larger sample of accidents occurring in the U.S. (see Reference 13). This study used HFACS as a tool to analyze the unsafe acts of aircrew in Australian and to compare them with the unsafe acts of aircrew in accidents in the U.S. based on 10 years of Australian and U.S. accident data. The Australian results showed that the most prevalent unsafe acts were skill-based errors, followed by decision errors, violations and perceptual errors. The comparison with the U.S. accidents demonstrated a similar pattern. The results of the study indicated that the great gains in reducing aviation accidents could be achieved by reducing skill-based error. Moreover, improvements in aeronautical decision-making and the modification of risk-taking behavior could reduce aviation fatalities.

Although there are many applications of the HFACS methodology now being reported, many aviation occurrence investigation agencies do not adopt HFACS as a tool for HF investigation. The Department of Defense (DOD) of the United States is now one of the few organizations that has formally adopted HFACS as a mishap investigation and data analysis tool. Drawing from Reason's and Wiegmann and Shappell's concepts of active failures and latent failures, the DOD (ref. 14) developed a new taxonomy to identify hazards and risks called the DOD Human Factors Analysis and Classification System (DOD HFACS). The DOD has issued a DOD Human Factors Guide to explain procedures for using DOD HFACS for all DOD persons who investigate, report, and analyze DOD mishaps.

The ASC's study

In 2008, a small research team was formed within the ASC to evaluate the feasibility of using HFACS as a tool for HF investigations. Three engineers with basic HF training were selected as the analysts and then sent to a 3-day HFACS training course instructed by the developers of HFACS to familiarize themselves with knowledge of the framework. After receiving the formal training, the three analysts classified both latent and active failures of 30 investigation reports, including 21 commercial aircraft occurrences, 5 general aviation occurrences, and 4 government aircraft occurrences conducted by the ASC between 1999 and 2007.

In each report, flight operational failures related to HF were classified by each analyst independently by using the HFACS checklist for aviation. The results of the classification were compiled and unified in the end by eliminating discrepancies through discussion. The analysts were allowed to consult senior investigators about the details of the occurrences during the process.

Results and discussions

The following are some preliminary results of the study.

After reviewing the ASC's previous occurrence reports, the research team found that some actions or behaviors of the pilot can only be recognized as "unsafe acts," i.e., level 1 of the HFACS taxonomy. Those actions or behaviors could be fitted into the subcategories of "unsafe acts," because the research team was unable to classify those actions or behaviors further, such as skill-based errors, decision errors, perceptual errors, and even routine or exceptional violations. This is mainly because of the insufficiency of information in the reports, which could result from investigators' writing as well as integrating techniques, or the incompleteness of factual data collection in the initial stage of the investigation.

For example, one of the ASC's reports stated *The flight crew did not follow the standard procedures to initiate a turn when conducting the "EMER DESCENT" procedures.* This finding clearly stated that the flight crew did not follow the procedures. Was it an error? Could it be a violation? According to Reason (1990), errors represent the mental or physical activities of individuals who fail to achieve their intended outcome. Meanwhile, violations signify the behaviors of willfully disregarding the rules and regulations that govern the safety of flight. The difference between errors and violations is the "intention" of the operator. When applying HFACS, the first step is to classify the unsafe act either an "error" or a "violation." If the "intention" of the operator was not described in the report, the research team would consequently not be able to classify the unsafe acts correctly.

In addition, the report stated that the pilot maintained a heading instead of following the QRH to initiate the emergency descent in a turn. Since there was no description of "why" the pilot did not initiate the descent in a turn to avoid interfering with other traffic, increase descent rate, and diminish the negative G force, such as "pilot focused on other matters and then forgot to initiate the descent in a turn" or "pilot decided not to initiate the descent in a turn for some reason," the research team, as well as the general readers, cannot determine whether this unsafe act is a skill-based error or a decision error.

The research team also discovered that in some reports, though the pilot's unsafe acts have been clearly pointed out, the factors contributing to these unsafe acts, the upper levels of the HFACS were not completely considered or mentioned.

For example, one of the reports stated: *The pilot did not make standard callouts to exchange critical information and execute cross check after the TCAS traffic advisory (TA) warning been announced (note: translated from Chinese).* After reviewing the CVR transcript, the research team found the flight crew also received an ATC instruction right after the TCAS TA warning, and the TCAS resolution advisory (RA) warning was issued 5 seconds after the ATC instruction. The circumstances that the flight crew faced at the time all happened in rapid succession, thus the research team believed there should be a factor regarding "insufficient reaction time," level 2 of the HFACS taxonomy that contributed to the flight crew's unsafe acts. However, this influential precondition of the pilots' reactions to the TCAS TA situation was not discussed in the report.

As recommended in Chapter 6 of ICAO Annex 13, the body of the ASC's occurrence investigation report comprises four chapters: factual information, analysis, conclusions, and safety recommendations. Most of the general readers only read the conclusions, Chapter 3 of the investigation report, because they do not have the time or patience to read it entirely. For this reason, the conclusions of the investigation report must be complete and consistent when compared to the factual information and analysis, Chapters 1 and 2.

The research team used the HFACS to classify failures in Chapter 1, 2, and 3 separately, and then compared the classification results of Chapter 1 and 2 with Chapter 3. By doing this, the research team hoped to recognize whether the content in Chapter 3 is complete, systematical, and sufficient to represent the whole report.

The results of the comparison showed that investigators may leave out some information during the process of condensing the conclusions from the factual and analysis information. For example, one conclusion in the report stated: *After the aircraft developed a stall and an abnormal attitude, the recovery maneuvering did not comply with the operating procedures and techniques for recovery of unusual attitudes.* In Chapter 2, the analysis section of the report, there were descriptions of pilot's unsafe act during abnormal attitude recovery maneuvering as well as the preconditions contributing to it. However, in Chapter 3, the conclusions did not include all information except for the unsafe act of the pilot. If a reader reviews the conclusions only, he or she will not have a complete picture of what really happened and why the pilot conducted the unsafe act.

Benefits of applying HFACS to occurrence investigation

Based on the preliminary results of the study, the research team believes that HFACS may benefit the investigations in the followings ways.

Developing a HF investigation checklist

The four-level, 19-category HFACS framework encompasses various HF theories and describes causal relationships among them. Developing a HF investigation checklist based on HFACS framework and integrating other checklists described in the *ICAO Human Factors Digest* (see Reference 2) could be feasible. The research team anticipates this checklist would be very helpful to the investigators while collecting HF-related information.

Confirming the completeness of factual data collection

After collecting a certain amount of factual data, investigators can tentatively utilize HFACS to classify the unsafe acts. If there are difficulties classifying or finding the preconditions, supervision, and organizational influences of those unsafe acts, more factual data collection is needed. After a pause, investigators may realize what areas need further attention.

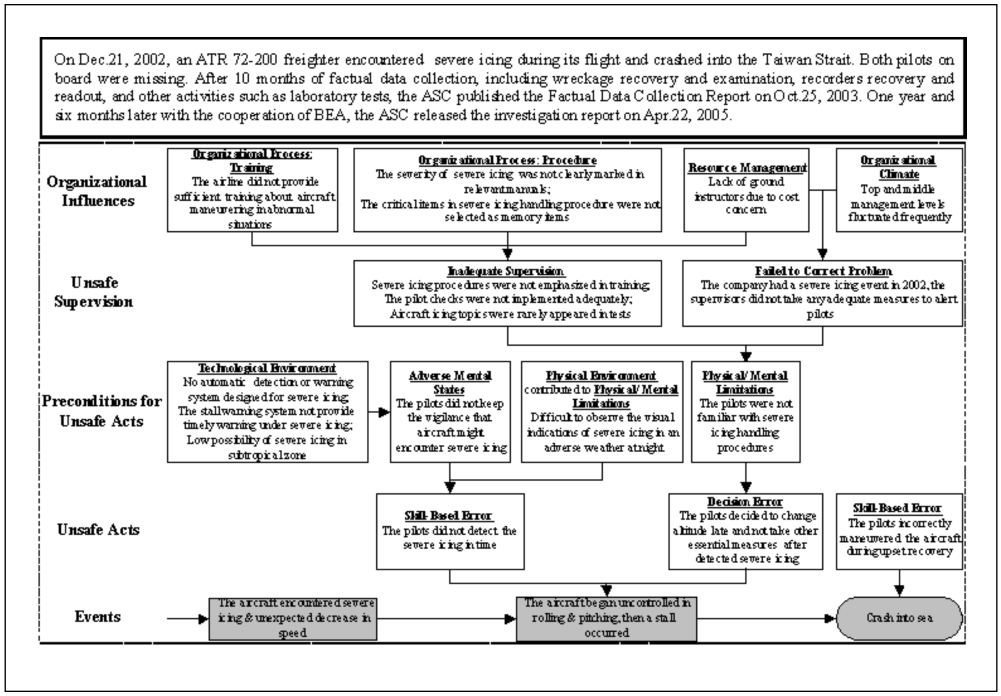

Figure 2. An example of drawing a diagram of HFACS classification results.

Let's look at an example.

During the landing roll of the Boeing 747, with half length of the runway remaining, the pilot-in-command attempted to exit the runway by using the body gear steering. The pilot-in-command, however, failed to turn the aircraft onto the taxiway. The aircraft consequently hit a protruded concrete manhole and stopped on the grass strip.

According to the flight data recorder, the ground speed of the aircraft was near 76.8 knots when the pilot-in-command initiated the left turn by using the body gear steering. Meanwhile, the operations manual states the body gear steering is not intended for speeds above 20 knots.

Obviously, there was a pilot's unsafe act during the landing roll. However, when trying to classify this unsafe act into HFACS framework, the research team found that the information is insufficient to determine if it was a skill-based error, decision error, exceptional violation, or routine violation. Only if the analysts learn more essential information can they complete the classification.

Examining the integrity and logicality of report

In the final stage of the investigation, investigators need to determine the causal factors and derive the conclusions and recommendations from factual data and analysis. To ensure all underlying and immediate causes were considered in the report, investigators can integrate the HFACS model with some analytical techniques, such as the Events and Causal Factors Analysis technique, for examination.

Drawing a diagram of HFACS classification results can clearly indicate the relationship and sequence within various factors in the report. Investigators can examine the logic and connections of analysis and conclusions to see if they were all supported by evidence. The diagram also provides a communication platform for all parties involved in the investigation. Figure 2 is an example of the diagram.

HFACS limitations

Currently, HFACS has some limitations when being applied to HF investigations. First of all, it was originally designed for military internal use in which all operational systems are within one organization. It points out what investigators should pay attention to and clarifies the connections among factors, yet it focuses on internal affairs only. In the civil aviation system, there are still many external, such as regulators, manufactures, and other service providers that may contribute to the occurrences. Those external organizational issues should

Conclusions

Most of the experienced investigators rarely, if ever, use specific checklists during the investigation. Accumulated experience and knowledge from years of conducting occurrence investigations developed their capabilities for collecting evidence. They probably have been told and learned that occurrence investigation is not generally checklist-based due to the complexities of the occurrence. However, *checklists are useful aids in organizing and conducting the investigation of human factors,* as stated in the *ICAO Digest* (see Reference 2). For those investigators with less experience or little HF training background, checklists *can help them verify the thoroughness of the investigation of the relevant human factors issues and help them organize and prioritize the gathering of evidence.*

The concept of the HFACS is quite understandable and adoptable. Compared to some well-known HF analysis approaches or theories developed from cognitive, behavioral, aeromedical, psychosocial, and organizational perspectives, such as Reason and SHEL models, HFACS is more complete and detailed for investigation purpose and usage. The research team believes that the ASC can reap great benefit by applying the concept of HFACS and adopting the checklist based on it, not only on the comprehensibility of HF data collection and analysis processes, but also the integrity and quality of the final reports.

As mentioned by the developer of the HFACS, it is not a "fix" framework. Safety investigators should continually review and update its contents according to the latest HF development and investigation experiences. The ASC HFACS research team has learned a lot through the process and will keep refreshing its knowledge to improve its investigations. The team values this experience and has the desire to study further. ◆

Acknowledgement

This project is supported by a grant from the National Science Council of Taiwan (NSC 97-3114-P-707-001-Y). Authors would like to express their appreciation to the NSC and the ASC for providing a financial endowment to carry out this research.

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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.

Dr. Scott Shappell is a professor of industrial engineering at Clemson University. Before joining the faculty at Clemson, Dr. Shappell was the Human Factors Research Branch manager at the Civil Aerospace Medical Institute. In addition, he has served for more than 16 years in the U.S. Navy as an aerospace experimental psychologist He has published/presented more than 200 papers, books, and presentations in the fields of accident investigation, system safety, spatial disorientation, sustained operations, and fatigue. Dr. Shappell received a B.S. in psychology (1983) from Wright State University graduating summa cum laude with honors in psychology and a Ph.D. in neuroscience from the University of Texas Medical Branch in 1990.

Dr. Douglas A. Wiegmann is an associate professor of industrial and systems engineering at the University of Wisconsin. Before joining the faculty in Madison, Wisc., he was a National Institutes of Health Roadmap Scholar at the Mayo Clinic College of Medicine where he also served as the director of human factors and patient safety research within the Division of Cardiovascular Surgery at Mayo. A private pilot, Dr. Wiegmann has also been an associate professor of human factors at the University of Illinois in Urbana-Champaign. Dr. Wiegmann received his Ph.D. in cognitive psychology in 1992 from Texas Christian University and formerly served as an aviation psychologist and accident investigator for both the National Transportation Safety Board and the United States Navy.

In recent years, the aviation industry has focused more and more on the evaluation and assessment of human factors associated with accidents and incidents. This may be because the percentage (and absolute number) of aviation accidents attributable solely to mechanical failures has decreased remarkably over the past 40 years, but the percentage of aviation accidents due to human factors has remained between 70% and 80% (O'Hare et al., 1994; Wiegmann & Shappell, 2003).

To address the human component of aviation safety, many in the field have turned to a system safety for answers. While there are several variations to the basic approach, most models of system safety include the following components: data acquisition, hazard identification, hazard assessment, identification of intervention strategies to address specific hazards, an assessment of those strategies, intervention implementation, and system monitoring. Ideally, this is a dynamic process involving the real-time identification of hazards, identification and implementation of interventions, and some process for monitoring changes in the system.

General aviation hazard identification and assessment

In 1999, the FAA began using the Human Factors Analysis and Classification System (HFACS) as a tool to examine human factors associated with general aviation (GA) accidents. Based, in part, upon Reason's (1990) "Swiss cheese" model of human error, HFACS is a theoretically derived model of human error that describes human factors at each of four levels: 1) unsafe acts of operators (e.g., aircrew, maintenance personnel, and air traffic controllers), 2) preconditions for unsafe acts, 3) unsafe supervision, and 4) organizational influences. A brief description of each category is included in Appendix A. For a complete description of the HFACS framework, see Wiegmann and Shappell, 2003.

Originally developed for use with the United States Navy/Marine Corps, HFACS has since been employed in a variety of military (e.g., U.S. Army, U.S. Air Force, Royal Dutch Air Force, Hellenic Air Force, and Indian Air Force) and civilian aviation settings (e.g., Australian Transportation Safety Board, Air Canada, and Alaska Airlines), as well as other high-risk industrial environments like rail, mining, oil, and medicine. Particularly germane to this report is a series of investigations of GA accident data conducted by the FAA over the last several years (Detwiler et al., 2006; Shappell & Wiegmann, 2001, 2003a, 2003b, 2003c, 2004; Shappell et al., 2006; Wiegmann & Shappell, 2001a, 2001b, 2003; Wiegmann et al., 2005).

Identification of GA hazards

Representative of the body of work referenced above was the examination of more than 14,000 GA human-factors-related accidents occurring between 1990 and 2000, described by Wiegmann et al., 2005. Using the HFACS framework, several interesting findings emerged (see Figure 1, following page).

Second, skill-based errors were the most prevalent form of human error associated with GA accidents—having been implicated in roughly four out of every five accidents since 1990. This is not to say that poor decisions did not figure prominently in GA accidents. After all, nearly a third of all fatal GA accidents were associated with at least one decision error and a little less than 20% were associated with violations of the rules. In contrast, perceptual errors (often due to visual illusions and spatial disorientation) were associated with considerably fewer accidents. Moreover, this pattern of human error was evident whether one looked at all human causal factors or just the first human cause factor in the temporal chain of events leading to the accident.

Finally, while the percentage of fatal and non-fatal accidents associated with skill-based, decision, and perceptual errors was relatively equal, the proportion of accidents associated with violations was considerably higher for fatal accidents. In fact, the data suggest that

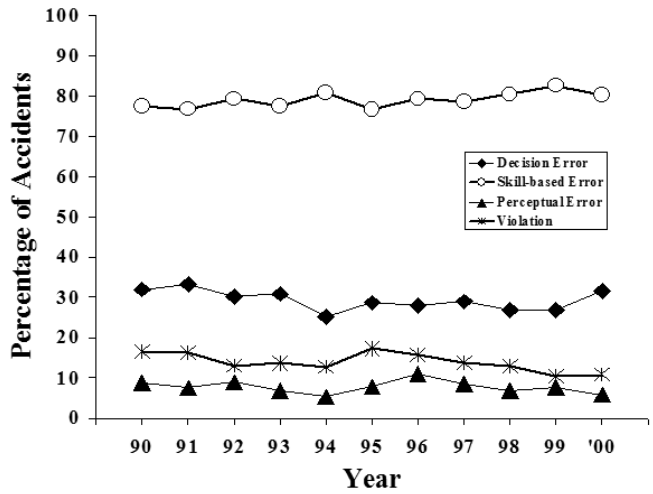

Figure 1. Percentage of accidents associated with at least one instance of a given unsafe act. Note that because each accident can be associated with multiple causal factors, the percentage of accidents for a given year will not equal 100%.

	Organizational/ Administrative	Human/ Crew	Technology/ Engineering	Task/ Mission	Operational/ Physical Environment
Decision Errors					
Skill-based Errors					
Perceptual Errors					
Violations					

Figure 2. The Human Factors Intervention matriX (HFIX). For simplicity, only the four unsafe acts are illustrated.

Aircrew Unsafe Act	Frequency (Percentage)
Skill-Based Errors	
Directional control on the ground	2,345 (12.9%)
Airspeed	2,008 (11.1%)
Stall/spin	1,400 (7.7%)
Aircraft control in the air	1,359 (7.5%)
Compensation for wind conditions	1,179 (6.5%)
Total Skill-based Errors Committed	18,136 (100%)
Decision Errors	
Inflight planning/decision-making	1,061 (18.2%)
Takeoff/landing from unsuitable terrain	431 (7.4%)
Preflight planning/making	393 (6.7%)
Refueling	367 (6.3%)
Go-around	354 (6.1%)
Total Decision Errors Committed	5,845 (100%)
Violations	
VFR flight into IMC	269 (10.7%)
Operating with known deficiencies	269 (10.7%)
Failure to adhere to procedures/directives	260 (10.4%)
Flight into known adverse weather	223 (8.9%)
Aircraft weight and balance	162 (6.5%)
Total Violations Committed	2,503 (100%)

Table 1. Specific Types of Errors Associated with General Aviation Accidents[1]

[1] Perceptual errors are not shown due to the low frequency.

pilots who violate the rules and are involved in an accident are four times more likely to perish or fatally injure someone. This latter finding was particularly striking since pilots are repeatedly told that the "rules are written in blood"—a lesson apparently true even today.

Assessment of GA hazards

The next logical step was to assess the hazards within each HFACS error category (e.g., skill-based errors, decision errors, perceptual errors, and violations) and which errors were most common. A summary of the GA hazard assessment is presented in Table 1. The numbers alone would seem to imply that the largest threat to GA safety are skill-based errors like directional control on the ground (e.g., ground loops) as well as concerns regarding control of airspeed and flight controls leading to inadvertent stalls/spins. Equally important, however, were inflight planning and decision errors, as were violations associated with visual flight rules (VFR) flight into instrument meteorological conditions (IMC), particularly given the emphasis within the FAA on reducing fatal GA accidents (FAA, 2006). Notably, while the loss of directional control on the ground occurs quite frequently, it typically does not result in fatalities. By comparison, stalls/spins, errors associated with inflight planning/decision-making, and VFR flight into IMC may not occur as frequently but are often fatal when they do.

GA intervention identification and assessment

It would appear that with the addition of tools like HFACS within the human factors system safety process, we might be better able to identify and assess hazards associated with GA operations using existing NTSB accident records. The next step in the human factors system safety process is to identify and assess current, planned, and other potential interventions to address the hazards identified above. One system safety tool that may assist in that process is the Human Factors Intervention Matrix (HFIX; Shappell & Wiegmann, 2006).

The HFIX tool contrasts the causal factors identified within HFACS against five approaches to accident intervention and mitigation identified in the literature (see Figure 2). While a complete description of HFIX is beyond the scope of this review, in general HFIX employs five broad areas around which interventions can be developed: 1) organizational/administrative, 2) human/crew, 3) technology/engineering, 4) task/mission, and 5) operational/physical environment. Each is briefly summarized in Table 2. For a more complete description, please see Shappell & Wiegmann, 2006.

In effect, by mapping prospective interventions onto the HFIX matrix, it would be apparent to senior officials within the FAA the breadth of a proposed safety program (i.e., is the program uni- or multidimensional?) and the exact aspects of human behavior that were targeted. Given that human error is, by its very nature, complex and multidimensional, it seems reasonable that any strategy for addressing it would likewise be multidimensional and represent a "strategy" or "program," rather than an individual intervention, per se.

In addition, HFIX could be used proactively to determine which areas an organization has "covered" and where gaps exist given current trends in the error data. For instance, if decision-makers knew that the largest threat to GA safety was skill-based errors (as was shown above), followed by decision errors, violations, and perceptual errors, HFIX could be used to determine if proposed and

Organizational/Administrative
Human Resource Management: Adequacy of staff in specific situations, the need for additional personnel, and the evaluation of individual skills of employees.
Rules/Regulations/Policies: Issuing, modifying, establishing, amending, and/or reviewing policies, rules, or regulations.
Information Management/Communication: Improvements in disseminating, storing, archiving, and publishing information. Also included are recommendations regarding collection of data, issuing information, and reporting activity.
Research/Special Study: Conducting research to determine the impact of recent technological advances or call for special studies to review processes, develop/validate methodologies, etc.

Task/Mission
Procedures: Amending, reviewing, modifying, revising, establishing, developing, and validating procedures.
Manuals: Reviewing, revising, issuing, and modifying manuals, bulletins, checklists, and other instructions or guidance.

Technology/Engineering
Design/Repair: Specific manufacturing changes including the design of parts. Also included is the modification, replacement, removal and/or installation or repair of parts and equipment.
Inspection: Maintenance inspections, overhauling, detecting damage including such day-to-day operations as inspecting fuel, oil level, and recommended safety checks.

Operational/Physical Environment
Operational/Physical Environment: Modifications to the operational environment (e.g., weather, altitude, terrain) or the ambient environment, such as heat, vibration, lighting, and eliminating toxins to improve performance.

Human/Crew
Training: Reviewing, developing, and implementing training programs. Also included is the training of personnel in handling emergencies.

Table 2. Brief Description of HFIX Intervention Categories

HFACS UNSAFE ACTS \ INTERVENTIONS	Organizational/ Administrative	Human/ Crew	Technology/ Engineering	Task/ Mission	Operational/ Physical Environment
Decision Errors	25.9%	26.9%	13.4%	5.7%	0.8%
Skill-based Errors	13.8%	20.7%	12.5%	2.4%	0.2%
Perceptual Errors	9.0%	12.7%	12.4%	2.4%	1.1%
Violations	14.3%	7.8%	2.8%	1.3%	0.7%

Figure 3. The percentage of JSIT recommendations classified by intervention approach and HFACS unsafe act. Note that while the percentage of recommendations across intervention approaches will add up to 100%, those across categories of unsafe acts will not. See the text above for an explanation.

future interventions have the potential to address those needs and which areas are currently being targeted. Furthermore, it would be possible to refine intervention identification and assessment if one knew exactly what type of skill-based error or other unsafe act was to be addressed.

To assess these proposed safety programs, 18 graduate students with aviation experience and graduate-level human factors training independently classified more than 600 Joint Safety Implementation Team (JSIT) recommendations into one of the five HFIX intervention approaches. In addition, the raters were instructed to identify any HFACS unsafe acts categories (i.e., skill-based errors, decision errors, perceptual errors, and violations) they felt the intervention would impact. This latter task could involve multiple categories, since many interventions addressed more than one aircrew unsafe act.

The findings demonstrated that as with an earlier examination of NTSB recommendations (Wiegmann & Rantanen, 2003), roughly a third of the JSIT recommendations involved organizational/administrative interventions. Likewise, many (22.2%) of the recommendations involved technological/engineering approaches. However, unlike the NTSB where relatively few recommendations directly targeted changes with the human/crew, nearly a third of those obtained from the JSITs did so.

As for what types of aircrew unsafe acts were targeted, it was not entirely surprising that interventions aimed at decision errors were associated with nearly three out of every four JSIT recommendation examined. In contrast, skill-based errors were associated with roughly half of the recommendations followed by perceptual errors (37.6%) and violations (26.9%). These numbers are noticeably different from the percentage of accidents associated with each type of error where skill-based errors account for nearly 80% of the GA accidents examined. Indeed, while roughly a third of the accidents were associated with decision errors, 72.6% of the interventions appeared to target pilot decision-making.

This is not to say that there should be a one-to-one relationship between the percentage of accidents associated with a given error category and the percentage of recommendations targeting their reduction. After all, it may take more effort to address one error form than another. Besides, more interventions may naturally address pilot decision-making. Likewise, human errors are not necessarily orthogonal. That is, one type of error may lead to another (e.g., a bad decision can set a pilot up for a skill-based error). Regardless, the global analysis presented here suggests that additional review of this apparent incongruity may be warranted.

Perhaps more important, however, was the mapping of each intervention within both the intervention approach and the HFACS unsafe acts category (Figure 3). As can be seen, three of the 20 possible elements within the HFIX framework (organizational/administrative by decision error, human/crew by decision error, and human/crew by skill-based error) contained 20% or more of the JSIT interventions. As before, the percentages within the matrix will not add up to 100% because each intervention can be judged to affect multiple HFACS unsafe acts.

On the surface, this appears to reflect a somewhat narrow rather than a broad approach to accident intervention/mitigation by these committees. Not that the interventions contained within these categories would not be effective, just that other, potentially equally viable, interventions may have been overlooked.

It is also interesting to note that if one examines the elements that contained between 10-20% of the possible interventions, nearly all of the remaining boxes among the organizational/administrative, human/crew, and technology/engineering approaches were included. What were not accounted for were human/crew and technology/engineering approaches dealing with the willful disregard for the rules and regulations (i.e., violations). Likewise, administrative approaches for addressing perceptual errors were below 10%.

Equally notable was the general lack of interventions targeting the specific task/mission of the aircrews or the environment they were faced with. Perhaps a closer examination of the type of operations GA aircrew are engaged in or the environments they are exposed to would prove fruitful in the development of additional interventions. Regardless, these findings suggest that there may have been options that were not considered as important by these select committees.

Examination of current safety programs

While the HFIX analysis of JSIT data examined future safety programs, a similar analysis of the FAA's National Aviation Research Program (NARP) would provide the best estimate of current safety programs. That is, the NARP describes current research, engineering, and development (R, E, & D) programs aimed at the development and validation of technology, systems, design, and procedures that directly support six of the agency's principal operational and regulatory responsibilities: acquisition, air traffic services, certification of aircraft and aviation personnel, operation and certification of airports, civil aviation security, and environmental standards for civil aviation. Of particular interest to this analysis were those R, E, & D programs with potential use within GA.

In much the same manner as the study examining future safety programs, 42 FAA aviation safety inspectors (n=33), air traffic controllers (n=3), and managers (n=6) attending a weeklong Department of Transportation-sponsored human factors accident investigation course were asked to independently classify 273 separate R, E, & D programs funded between 1999-2005 into one of the five HFIX intervention approaches. In addition, the participants were instructed to identify any HFACS unsafe acts categories they felt the intervention would impact. The one notable difference between the studies was that in this study the data set was randomly parsed so that at least five (but as many as nine) respondents independently reviewed each R, E, & D program. A simple majority was required for any category to be counted.

Another important difference was that rather than targeting GA safety alone, many of the R, E, & D programs were aimed at both GA and air carrier aviation. Instead of trying to distinguish which particular type of operation a given program currently targeted, all human factors programs were considered. This was done because many successful air carrier safety programs, like LOSA and FOQA, have potential uses within GA.

As with the JSIT (future program) analysis, nearly a third of the R, E, & D programs involved organizational/administrative approaches that focused on such things as developing non-precision global positioning sensor (GPS) routes for emergency medical facilities and establishing certification standards for GA auto navigation and control systems using pilot performance data and flight simulation. Considerably fewer R, E, & D efforts were human-centered (15%) while decidedly more utilized technology (more than 40%) to improve safety. Obviously, technology that provides pilots better weather information in flight can increase aviation safety. However, developing programs that train pilots to recognize hazardous weather and make judicious inflight decisions might also be of use. Like the JSIT interventions, few R, E, & D efforts targeted changes within the task/mission or operational/ physical environment.

The R, E, & D efforts associated with the HFACS unsafe acts were surprisingly similar to those proposed by the JSITs. The overwhelming majority (71.8%) of the R, E, & D efforts targeted pilot decision-making with decidedly fewer targeting skill-based errors (40.3%) and perceptual errors (34.4%). Perhaps most surprising in the analysis of R, E, & D programs was the finding that very few (less than 15%) were aimed at violations of the rules. Remember, the SMEs were permitted to identify all the unsafe acts that they felt would be affected by a given R, E, & D program.

INTERVENTIONS

HFACS UNSAFE ACTS	Organizational/ Administrative	Human/ Crew	Technology/ Engineering	Task/ Mission	Operational/Physical Environment
Decision Errors	21.6%	13.2%	30.4%	3.3%	3.3%
Skill-based Errors	11.7%	10.6%	13.2%	3.7%	1.1%
Perceptual Errors	7.0%	3.7%	19.8%	2.6%	1.5%
Violations	7.3%	2.6%	2.2%	0.7%	0.4%

Figure 4. Percentage of R, E, & D programs classified by intervention approach and specific HFACS unsafe act addressed. Note that while the percentage of recommendations across intervention approaches will add up to 100%, those across categories of unsafe acts will not. See the text above for an explanation.

INTERVENTIONS

HFACS UNSAFE ACTS	Organizational/ Administrative	Human/ Crew	Technology/ Engineering	Task/ Mission	Operational/Physical Environment
Decision Errors	24.5%	22.6%	18.6%	5.0%	1.6%
Skill-based Errors	13.2%	17.6%	12.7%	2.8%	0.5%
Perceptual Errors	8.3%	9.9%	14.6%	2.5%	1.2%
Violations	12.2%	6.2%	2.6%	1.1%	0.6%

Figure 5

When mapping the NARP R, E, & D programs onto both the intervention approach and HFACS unsafe acts category some similarities with the JSIT data emerged (see Figure 4). For instance, organizational/administrative approaches that target pilot decision-making accounted for a large percentage (21.6%) of the R, E, & D efforts examined. However, nearly a third of the R, E, & D efforts focused on some sort of technology aimed at improving pilot decision-making—some 17% higher than that seen with the JSIT recommendations. Surprisingly few interventions targeted violations of the rules—less than 10% across the board and less than 5% if organizational/administrative approaches were not considered. As with the JSIT interventions, very few R, E, & D programs examined targeted improvements associated with the task/mission or the operational/physical environment.

In an effort to evaluate the entire spectrum of safety programs (those currently in place, under development, or proposed for the future) the two matrices were combined. Judging from Figure 5, the largest share of safety initiatives is targeting decision and skill-based

Intervention					
Standardize initial flight training that covers VFR into IMC.	4.8	4.2	4.6	4.0	4.4
Require spatial disorientation training for all pilots.	4.6	4.4	4.4	4.0	4.4
Make VFR into IMC training a special emphasis on the biennial flight review.	4.4	4.0	4.6	4.2	4.3
Conduct awareness training within ground school that demonstrates flight in weather (e.g., videos of A/C exceeding structural capabilities).	4.4	4.4	4.2	3.8	4.2
Include training on the importance of communication and radio calls for items that may seem trivial or embarrassing (e.g., informing ATC that unfamiliar with the area).	4.0	3.6	4.6	4.4	4.2
Require that instructors are able to complete all the maneuvers they teach.	4.4	3.8	4.2	4.2	4.2
Add a weather update to the enroute checklist.	3.8	3.6	4.0	5.0	4.1
Create an incentive program that teams with insurance programs.	4.2	4.0	3.6	4.0	4.0
Mandate minimum standards and training for all equipment used in an aircraft.	4.2	4.0	4.2	3.4	4.0
Include training on decision-making versus skill in dealing with the hazards of flying in IMC.	4.0	3.6	3.8	4.2	3.9

Table 3. Top 10 Interventions by Average on a Scale of 1 "Worst" to 5 "Best"

errors with the former occupying more attention than the latter. Indeed, nearly one quarter of the safety programs involve organizational/administrative approaches that target pilot decision-making with only slightly fewer crew-centered approaches targeting the same type of error. Even the third most populated element was associated with technology that targeted pilot decision-making (18.6%).

Notably, there were few initiatives aimed at violations of the rules such as continued VFR flight into IMC. While just more than 10% of the JSIT and NARP programs addressed violations from an organizational/administrative point of view, there were relatively few programs addressing the issue using different approaches. This may be due to the fact that the FAA is heavily invested in ensuring compliance at a variety of levels and/or the concern that enforcement approaches may not be the only answer. In other words, these findings may simply reflect inherent difficulties associated with addressing violations or a need for a more creative approach to the issue remains to be explored. Regardless of the reasons, this may be one area that would benefit from a more creative approach to intervention development.

Intervention generation and evaluation using HFIX

One area of particular interest to the FAA is flight into adverse weather. During the last 20 years, nearly 40,000 general aviation (GA) aircraft have been involved in accidents—of which roughly 20% involved fatalities (Shappell & Wiegmann, in press). Tragically, many of those fatal accidents involved encounters with adverse weather (Detwiler, Boquet, Holcomb, Hackworth, Wiegmann, & Shappell, 2006; Wiegmann, Boquet, Detwiler, Holcomb, Faaborg & Shappell, 2005; NTSB, 2005).

To illustrate how HFIX can be used in an intervention generation mode rather than simply an intervention evaluation mode we enlisted the support of several aviation experts. In the first phase (intervention development), 218 participants with expertise in a variety of aviation specialties (i.e., pilots, flight instructors, student pilots, aerospace engineers, air traffic controllers, mechanics, aviation administrators, government regulators, and aviation faculty) were enlisted from five locations: Embry-Riddle Aeronautical University (ERAU), the Canadian Helicopter Corporation (CHC), the Transportation Safety Institute (TSI), the Federal Aviation Administration (FAA), and Alaska Airlines.

At each location, participants were split into five groups of similar sizes. Each group was assigned a particular approach and instructed to generate as many interventions within that particular approach as possible. For instance, if assigned to the human/crew approach participants were instructed to generate programs that would reduce the likelihood that a pilot would initiate flight into adverse weather only by changing the behavior of the aircrew. Ideas such as "conducting annual training to review/enhance knowledge of the adverse effects of weather on flying" and "creating a mentoring program for all new pilots" were typical of these groups.

The interventions were then given to five pilot-SMEs for prioritization. All had served previously as pilot-SMEs during the coding of human causal factors using the HFACS framework in the studies reported earlier. Using a scale of 1 to 5 with 1 representing "low" or "poor" and 5 representing "high" or "excellent" each pilot-SME was asked to rate each prospective intervention on each of four dimensions: effectiveness, feasibility, acceptability, and cost. These dimensions were chosen because they have been used successfully in the past by the JSIT. Clearly, factors such as effectiveness (i.e., What is the likelihood that it will reduce GA accidents?), cost (i.e., Can the organization afford the intervention?), feasibility (i.e., How easy will it be to implement the intervention or does it actually exist?), and acceptability (i.e., Will the pilot community accept the proposed intervention?) are all important to the successful employment of safety interventions. Likewise, cost is of tremendous concern among many organizations—particularly during times of fiscal austerity.

There are many ways to analyze the intervention rankings using the four dimensions (feasibility, acceptability, cost, and effectiveness). For instance, one could treat each dimension equally and merely sort the potential interventions based upon the overall average of the four ratings. By treating each dimension equally, a "top 10" list of interventions was identified and is presented in Table 3.

What is apparent from the list is that many involve some degree of training. Whether that training deals with preventing pilots from flying into instrument conditions (i.e., information regarding the hazards associated with VFR flight into IMC beyond current levels) or how to survive once one gets there (e.g., spatial disorientation training and the importance of communicating with air traffic control and flight service stations when in adverse weather), many of the higher rated interventions seem almost intuitive. Indeed, many are already being considered at some level within the GA community. In those cases, this analysis may provide some additional support for continuing existing efforts. In contrast, where the interventions identified here are novel, it may provide those charged with GA safety a fresh approach to a historical problem.

While considering all four dimensions equally has some appeal, many organizations are more interested in one characteristic (e.g., effectiveness) than another (e.g., cost). For instance, if the organization was most interested in whether a given intervention would be effective, the top-rated interventions may change. Depending upon how one weighs a given characteristic, different interventions may come to the top.

Discussion

There is no denying that system safety concepts have proven very beneficial within the aviation domain. However, its utility within human factors has yet to be fully leveraged within the aviation industry.

At a minimum, the studies presented here suggest that it is possible to integrate system safety concepts within GA human factors. In doing so, safety professionals and decision-makers within the

FAA have been provided a unique glimpse at the roots of many GA accidents—human error. Beyond that, existing and proposed interventions have been organized within a single matrix that integrates human error theory and human factors approaches to accident/incident prevention.

By combining both, it may now be possible for the FAA to put the intervention pieces together in such a way that they can obtain a "quick look" at the strengths and weaknesses of their safety initiatives.

Additionally, it provides decision-makers within the FAA the ability to ensure that a broad spectrum of interventions has been considered.

Where gaps exist, HFIX provides a means to "fill the gaps" and assess those interventions that are most likely to address a perceived human factors need.

In the end, it is hoped that tools like HFACS and HFIX will ensure that human factors system safety will become a reality and that ultimately GA accidents attributable to human error will be reduced. ◆

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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

Christine Negroni *is an aviation writer and safety specialist in New York. She reports on aviation for* The New York Times *and other publications. From 2000-2005. Negroni served on the FAA's Aging Transport Systems Rulemaking Advisory Committee (ATSRAC). She is the author of* The New York Times *notable book,* Deadly Departure: Why the Experts Failed to Prevent the TWA Flight 800 Disaster and How it Could Happen Again *(HarperCollins 2000) and the forthcoming* The Crash Detectives: The Forensics of Fatal Transportation Accidents.

Photo not available

Dr. Patrick Veillette *is a professional corporate pilot, air safety specialist, and aviation writer. His articles have appeared in* Aviation Safety Journal *and the* Flight Safety Digest. *He was named aerospace journalist of the year (safety category) by the Royal Aeronautical Society in 2007. In 25 years of piloting experience, he has accumulated more than 15,000 hours. Dr. Veillette is a 1983 graduate of the U.S. Air Force Academy and the author of* Loss of Control.

Aviation in the United States is a highly regulated environment, but air medical transport is an odd exception. Operating under different rules depending on the phase of flight, each air service sets its own standards for pilot qualifications, aircraft equipment, and use of safety apparatus.

In 2008, between helicopters and airplanes there were 16 crashes, 8 of them fatal, killing 28 people—5 of them patients. This was the deadliest year on record for air medicine, and it renewed attention on the safety issues in this industry. While this paper focuses attention on EMS aviation in the United States, use of aircraft to transport patients is growing through the world. The issues raised here are widely applicable.

It is important to discuss the history and evolving business model of EMS aviation in the United States to understand the pressures that have resulted from the growth of the industry and subsequent safety issues.

The authors have created the Comprehensive Medical Aviation Services Database (CMAS) comprised of accidents, incidents, events, and a review of reports from NASA's Aviation Safety Reporting System (ASRS) from 1985 to 2008. This is the information on which they rely to explain the special challenges in air medicine. Of the 1,132 air ambulances in the United States, nearly two thirds are rotorcraft. The inherent instability of helicopters, the high workload environment, and the often-unplanned nature of the inflight route and landing zone all contribute to the unique nature of helicopter ambulances. It is a vastly different world and a markedly more hazardous one than fixed-wing medical flights. For these reasons, helicopter EMS (HEMS) operations are the focus of this report.

Contemporary air safety philosophy values the analysis of incidents and events including self-reporting as a more proactive method of reducing risk. Toward that end, this paper analyzes FAA incidents, industry reported events, and 369 ASRS narratives filed anonymously by pilots who experienced a safety issue in flight as well as accidents investigated by the NTSB.

In reviewing incidents and events, such as aircraft malfunctions and adverse weather conditions, the threat-and-error management assessment model was used to see how these episodes were handled and if the threat progressed to an "undesired aircraft state."

The review shows that a large percentage of threats degrade to undesired aircraft states. The narratives of participants help to illuminate more thoroughly what happened, and some of those narratives are included in this paper.

Threats to safety will emerge in every flight. Removing the known threats is an important first step. The National Transportation Safety Board has issued multiple sets of safety recommendations going back to 1988. The Federal Aviation Administration has chosen to suggest rather than mandate many of these recommendations. The analysis of the CMAS Database and ASRS reports also leads the authors to make several safety recommendations.

History

The Royal Flying Doctor Service is probably the oldest air ambulance in the world, starting in 1928. A mission of the Presbyterian church, the service flew doctors to patients rather than the present model of flying patients to hospitals. In the United States, Schaefer Air Service in California started moving patients in specially equipped airplanes shortly after the end of the second World War.

It was the wartime practice of moving American casualties during conflicts in Korea and then Vietnam that inspired the idea of using helicopters to move the sick and injured in the civilian world. In 1972 St. Anthony's Hospital in Denver, Colo., became the first to offer helicopter ambulance services in the U.S.

From one in 1972, hospital helicopter ambulance programs grew quickly. There were 32 by 1980 and 174 by 1990, a fivefold increase. Entering the 21st century, the number of operators slowed but the number of aircraft flying continued to grow, from 231 helicopters in 2000 to 840 in 2008.

The increase was attributed to a 2002 change in federal Medicare policy that revised the fees operators would be paid, doubling and in some cases tripling reimbursement for flying patients. The Medicare fee schedule guaranteed a flat payment from the government. It also affected what private insurance companies would pay because often the insurance rate is pegged to Medicare's rate. Seemingly overnight private companies found it profitable to get into the business of medical transport.

What is medical transport?

The typical HEMS flight is defined by its atypicality. It can be any time of the day or night, departing and landing at helipads or on highway shoulders, carrying accident victims, premature babies, or organs for transplant. The constants are that the EMS helicopter pilot will operate under time pressure in a high-workload environment, often with a lack of enroute and/or destination information and weather reporting and will be expected to operate through obstacles and obstructions and into or out of non-standard landing zones including rooftops, highways, and parking lots.

The industry works under several important parameters. Federal and insurance payments have encouraged the growth of air medicine, and air medicine is considered vital and important in American society. Helicopter ambulance companies operate in an environment in which moving patients is the only method of generating a return on a capital-intensive investment. Payment for flights is based on geography—where the helicopter is flying—and distance—how far the patient is flown.

The reimbursement criteria means there is no business incentive for flying larger aircraft, twin-engine helicopters, or installing anything beyond the minimum required safety equipment. The decision of *what* safety equipment or *whether* to install safety equipment is left up to the operator.

As a result, less than half—40%—of HEMS operators have terrain awareness and warning systems (TAWS); slightly more than half—57%—use twin-engine aircraft and are therefore capable of autopilot or IFR; 30 % use night vision goggles; and less than 1% of HEMS operators fly two-pilot crews.

Rather than elevating industry standards, the geography/distance payment method depresses safety by pressuring conscientious companies to reduce their costs to match the lowest competitor as explained by Gary Sizemore, an EMS helicopter pilot and past president of the National EMS Pilots Association. "One company is flying substandard; it's using the cheapest aircraft available, saturating the area, flying with no safety equipment," he said. "It is going to cause the large vendor to reduce overhead to compete."

Since its first hearing on EMS safety in 1988, the NTSB has held two more hearings urging the Federal Aviation Administration to mandate certain equipment and operational practices. In 2009 the NTSB recommended requiring all EMS operators to operate under Federal Aviation Regulations Part 135 on all flights with medical personnel on board (A-06-12), requiring all EMS operators to use risk evaluation programs and train in the evaluation of flight risks (A-06-13), requiring EMS operators to use formalized dispatch and flight-following procedures including up-to-date weather information flight risk assessment decisions (A-06-14), and requiring the installation of terrain awareness and warning systems on aircraft and training flight crews on the use of this equipment (A-06-15).

While the authors agree with these recommendations, the following threat and error management review of the EMS accident and incident data leads us to suggest several others.

Threat and error management

A "threat" is an external event or an error outside of the flight crew's influence but requiring the active management of the crew to prevent it from impacting safety. An "error" is a deviation from organizational or crew expectations, and an "undesired aircraft state" is a compromised situation placing the flight at increased risk.

Pressure is the most common threat, present in 93% of all the pilot reports. This can be from insufficient time to prepare for a flight, patient conditions, management pressures, deteriorating weather, etc. An excellent example is contained in the following pilot narrative.

"The flight was flying from a hospital with a patient on board. The rain had picked up, and the visibility was less than reported.... I was able to maintain a couple of lights to the side but forward lights all disappeared.... The problem is having a patient on board and feeling the pressure to try to continue the flight in less than reported conditions. They had disconnected the autopilot so it was inoperative. I am ATP rated but not current IFR. We do have an IFR ship that should have been sent on the flight but we are closer by 18 mi (sic) and our ship is much cheaper to fly.... It is too bad that we sometimes have to have less than favorable flight to get non-aviation people to realize closer and cheaper are not always the right thing to do. (ASRS No. 635667)

Time pressure is commonly cited in ASRS and greatly increases the probability of human error. Dr. James Reason, professor emeritus at the University of Manchester and an expert on human error, found that the perception of a shortage of time increases the probability of human error by 11 times. The following ASRS narrative illustrates this point.

"I arrived at work for a shift change. After parking the car, I heard one of our hospital helicopters turning on the hospital helipad. I ran to the pad so I could relieve the night pilot and take the flight.... We were responding to a multiple car accident with serious injuries.... I remember glancing at my instrument gauges before lift off. Everything looked good. I made the appropriate calls and began the takeoff process.... As we moved forward, my warning lights and horns for low rotor rpm came on. My rotor rpm's began to drop, and the aircraft slowly began to settle.... I turned and was able to settle back on the pad and appeared to land without incident. I looked at the gauges and around the cockpit. Everything was normal again, except I noticed that my engine throttles were not full forward. I assumed that was the problem. I pushed the throttles forward completely, lifted off again, and flew the flight to the accident scene as if everything was normal. Upon landing and shutting down at the scene, I discovered that approximately 2-3 inches of each tail rotor blade (2) was chopped off. I gave the remaining rotors a detailed inspection and checked the drive train from the engines to the rotors and found everything in place. The patient was brought to the aircraft, dying, and placed inside. I made the decision that I could make the 5 minute flight back to the hospital safely. The flight went back without incident. *Problem areas: The quick EMS helicopter responses, the numerous interruptions of the EMS pilot during start-up and the pilot* *allowing this to happen. Plus, the added pressure of a dying person causing the pilot to make emotional decisions instead of safe ones.*" (Italic added for emphasis) (NASA ASRS Accession Number 118240)

The EMS pilot works in a "very high threat" mission environment. The excessive workload faced by helicopter ambulance pilots is most clearly present in 84% of the ASRS reports. These included workload induced by single-pilot operations in helicopters and the lack of a pilot monitoring for cross-checking. This is aptly stated by an EMS pilot in the following ASRS report.

"I was flying an EMS helicopter dispatched from XYZ hospital, in City A, to recover a patient at the mall, City B. The coordinates provided were incorrect and took me 5 nautical miles south of the City B airport before I recognized the error and reversed course. I was coordinating with dispatcher, medic command (flight-following/status reports,) and emergency vehicle on scene and broadcasting position reports and intentions on Unicom….The approach supervisor advised me that I entered his airspace and did not properly coordinate with his controller…. I was working four frequencies and receiving conflicting coordinates from the ground while searching for the landing zone. I was aware of my close proximity to the airport traffic area. I was preoccupied with the traffic avoidance while coordinating with the ground vehicles during the search for and subsequent approach and landing at the landing zone." (NASA ASRS Accession Number 181754)

With the exception of half-a-dozen hospital operators, HEMS operations are conducted with single-pilot crews. Single pilots lose the benefit of error management by cross-check and pilot monitoring.

HEMS great asset is the helicopter's ability to operate off-airport, at disaster scenes, highway accidents, and other inaccessible areas. However, "on scene" operations often present problems with inadequate information about weather and obstacles; 53% of the ASRS reports indicated this threat. Approximately 42% of these threats were not adequately managed.

Adverse weather conditions were present in 45% of the ASRS reports. This category included not only limited visibility and cloud ceilings that create higher risks for helicopter operations, but also weather forecasts with "chance of marginal conditions," or a lack of definitive weather reports along the route or destination, deteriorating weather, and unexpected weather. About 34% indicated this threat category was not adequately managed.

This, of course can lead to the threat of inadvertent penetration of instrument conditions, cited in 18% of the sampled ASRS reports; 78% occurred at night. The NTSB's 1988 study determined that the single most common factor in fatal EMS helicopter accidents was unplanned entry into instrument meteorological conditions. "Inadvertent IMC" should receive focused attention as it often results in a serious degradation of aircraft control (14% of the sampled reports) or a serious loss of separation with terrain (8% of the sampled reports.) Inadvertent IMC continues to be a large contributor to fatal EMS accidents.

Of the 210 accidents in the CMAS database over the past 20 years, 69—or one in three—involved the aircraft hitting something. Confined-area operations were present in 29% of the ASRS reports. HEMS pilots frequently deal with limited maneuvering room, proximity of obstacles, lack of information about obstacles, inadequate lighting to detect obstacles, adverse wind conditions during departure from a confined area, and a lack of guidance from the ground to avoid obstacles. Approximately 14% of the ASRS reports indicated this threat had not been adequately managed.

Pilot factors included fatigue and lack of IFR currency/proficiency. In its 1988 study, the NTSB suggested that pilot fatigue could be a primary contributor to the industry's poor safety performance. The topic of fatigue in EMS operations was revisited during the 2009 NTSB hearings on HEMS. This threat was present in 17% of the reports and inadequately managed in 9% of the time. The Safety Board believes "that EMS helicopter pilots work in an environment and operate on a schedule conducive to acute and chronic fatigue that can influence the pilot's ability to operate the aircraft safely."

Helicopter factors included the aircraft not being IFR capable, operating with inoperative components, and/or a mechanical failure. About 16% of the reports indicated the presence of this threat; and it was not properly handled 15% of the time.

These are the leading threats, and they have changed little since the Flight Safety Foundation's study of EMS safety in 2001 conducted by the author (Veillette, 2001), or for that matter, since the NTSB's first report on HEMS safety 21 years ago.

Given the frequency and severity of the IMC-related accidents, the NTSB has repeatedly warned about the weather minimums authorized for HEMS flights and has recommended the development of visual flight weather minimums for individual helicopter programs based on local terrain and weather. These weather minimums should be communicated to the pilots in writing, and deviation below the program minimums should be prohibited.

The FAA has recently implemented an amendment to weather minimums authorized for HEMS operators. Operating Specifications A021, "Helicopter Emergency Medical Services Operations," requires a minimum of 800-2 (800 foot ceiling, 2 nm visibility) for a "local" flight in day conditions, and 800-3 for a cross-country flight in day conditions. At night, an operator without a night vision imaging system or terrain awareness warning system will require 1,000-3 for local flights and 1,000-5 for cross-country flights.

This study compared the weather in 55 IMC-caused accidents occurring between April 1, 1988, and Sept. 27, 2009, against the recently amended weather minimums. In more than half of the 55 accidents the actual weather was better than the recently amended HEMS weather minimums. This shows that even without the existence of significant loopholes in the Part 135 weather minimums, this recent change to weather minimums may not have a wide-reaching effect.

Loopholes within the Part 135 weather minimums would still allow a pilot to launch into weather hazardous to the flight. One of these "loopholes" is weather forecasts that contain "probability of 'x' conditions" or "temporary" weather conditions. For example, a weather forecast may state, "Ceilings better than 3,000 feet and visibilities better than 5 miles…with a 40% chance of rain showers and occasional visibilities below 1 mile and ceilings below 800 overcast." Such a forecast would still allow a pilot to launch.

The lack of on-site weather reports also impacts the preflight go/no-go decision. Weather reports are often a significant distance from the destination, making it difficult for EMS pilots to make an educated decision. Examining NTSB accident reports, the nearest weather reporting stations in 10 accidents were 15 to 25 miles away, and in eight accidents the weather reporting was even more remote. One was 47 miles away.

Under Part 135 flight rules, pilots are still allowed to make their own weather observation. "For operations under VFR, the pilot-in-command may…use weather information based on the pilot's own observations or on those of other persons competent to supply appropriate observations."

In actual operation, EMS pilots often fail to keep their weather assessment objective. A review of ASRS reports for the Flight Safety Foundation's 2001 study found that an astounding 67% of the EMS pilot reports documented that knowledge of the patient's condition influenced their decision-making. A survey of flight paramedics conducted by the International Association of Flight Paramedics and presented at the NTSB's special hearing on EMS safety revealed 30% of the respondents reported that the pilot is aware of the urgency of the flight request, despite attempts to shield that information to avoid pressuring the pilot to conduct the flight.

In light of this reality, giving the pilot the authority to take off even in weather others would judge questionable should be addressed.

Since weather and reduced visibility (including night flight) creates layers of risk, management is required on several fronts. Since 1987, there have been 305 EMS helicopter accidents or significant safety incidents in the United States, according to the CMAS database, and nearly half of them occurred either at night or in weather that obstructed the pilot's vision.

In addition to changing weather minima, providing EMS pilots and dispatchers with more accurate weather information, and removing subjective decision-making in questionable weather with a formalized flight risk assessment program, EMS aircraft should be equipped to fly in these conditions. This is problematic since engine helicopters are unable to accommodate autopilots and IFR equipment and the recent trend is toward replacing twin-engine aircraft with single-engine for the fuel savings.

A number of aviation organizations, from the International Civil Aviation Organization to the Professional Helicopter Pilots Association, claim two-engine helicopters are important. The PHPA position is that the standard "should be a multiengine, fully IFR certified helicopter." Medical helicopters in Canada and air rescues conducted by the U.S. Coast Guard require two-pilots.

The ASRS reports feature stress as a recurrent theme. EMS piloting with high workloads and unpredictable operating environment has become its own "error trap." This makes the need for two pilots obvious.

In a study of turbine-engine airplane accidents, aviation research company Robert E. Breiling Associates of Florida, concluded that single-pilot flights are riskier than those with two pilots. The statistics show the risk of a fatal accident is 3.7 times greater with a single pilot. In publishing these findings, *AOPA Pilot* magazine wrote, "Single-pilot operations create higher workloads and greater demands on pilot skill when the chips are down and stress levels run high."

Behind the phenomenal growth of HEMS from one hospital in 1972 to the multimillion-dollar business it is today is a disturbing business model; fly the helicopters as inexpensively as possible—with one pilot and a minimum of safety equipment. This has created an inherently unsafe system. As one EMS pilot said, "If they knew what I knew, even the nurse and paramedic wouldn't get on board."

This report lists some of the recommendations made by the NTSB. Based on the threat and error management analysis of the ASRS data, further recommendations would improve safety for the industry as a whole and serve as guidance to other countries where the HEMS industry is not as well developed or as influenced by private for-profit operations. These include

- two pilot (IFR proficient and current), two-engine, IFR-qualified helicopter.
- advanced avionics (autopilot, satellite weather capability).
- night vision technologies.
- automatic dependent surveillance-B.
- scenario-based simulator training.
- a Safety Management System.
- further refinement and eventual approval of the HEMS weather tool.
- fatigue management. ◆

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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

__Ludwig Benner__ joined the NTSB in 1970 and headed its Hazardous Materials Division from 1976-1982. He has published more than 50 articles and a book on accident investigation process research. He has taught accident investigation and led development of investigation support software. Benner is a correspondent member of the European Safety and Reliability Data Association's Accident Investigation Project Group, chairman of ISASI's Board of Fellows, a Fellow of the International System Safety Society, and a retired professional safety engineer.

__Ira Rimson__ completed a Navy aviation career as director of safety of the Naval Air Systems Command. He joined senior FAA retirees founding Aviation Resources Group in 1981, heading its safety services. He has consulted and performed private safety investigations since 1977. Rimson is a Fellow of ISASI, the American Academy of Forensic Sciences, and the American College of Forensic Examiners and a senior member of the International System Safety Society.

Abstract

Recent high-visibility accidents demonstrate that processes for learning costly lessons that should have been identified by investigations continue to underperform expectations. The accident scenarios of the crash of a Continental-Colgan de Havilland Dash 8-Q400 at Buffalo, N.Y., and a FedEx MD-11 at Narita, Japan, a month later reflect missed opportunities to learn the lessons from similar previous accidents or analyses by those who might have used that knowledge successfully to avoid the latest crashes. Current processes for identifying, defining, communicating, and acting on lessons to be learned are inadequate to take advantage of the opportunities offered by investigated accidents. We undertook a systems analysis approach to define historical accident investigation lessons-learned processes and outputs and isolate and document the systems' boundaries, functions, and attributes. This paper documents our analysis and the insights gained. We incorporated the resulting successful functional elements into a "lessons learning system" that identifies a process from generations of lessons-to-be-learned source data to disseminating and applying lessons learned to improve the learning organizations' safety performance. We analyzed those elements from the standpoints of lessons-learned users, system developers, and designers, which enabled us to define 26 desired system attributes and at least eight strategic system design alternatives. We address these immediate needs for improving the lessons learning processes:

- redesigning the form and substance of lessons-to-be-learned source data to improve their usefulness and
- redefining investigation product specifications to require that lessons learned be an explicit documented product of investigation processes.

Background

"The official motto of ISASI is "SAFETY THROUGH INVESTIGATION." (See Reference 1.)

"**5. ACCIDENT PREVENTION …** Each member shall

"5.1 Identify from the investigation those cause-effect relationships about which something can be done reasonably to prevent similar accidents.

"5.3 Communicate facts, analyses and findings to those people or organizations that may use such information effectively…." (See Reference 2.)

ISASI was incorporated 45 years ago, and its official motto was adopted at that time. Its Code of Conduct has been in effect for more than 25 years. Recurrence of accidents from similar sources should have been reduced substantially, if not eliminated, had investigations fulfilled the expectations of ISASI's founders. What happened?

What happened has been the recurrence of accidents that bear striking similarities to those that have happened before. We call these recurrences "retrocursors." Unlike "precursors," which presage events to come in the future, "retrocursors" reenact behavior patterns that have led to accidents in the past. At the time of this paper's writing in late June 2009, the most recent of these was the loss of Air France Flight 447 over the equatorial Atlantic enroute from Rio to Paris. Facts are not yet adequate to support any of the many hypotheses, at least two of which have happened before—

- Air data inertial reference unit (ADIRU) faults resulting from errant input signals, with resulting reversion of control laws from (normal) computer control to one of three degraded levels demanding immediate manual control by the crew in an ambiguous situation. Out-of-envelope airspeed signals could have resulted from pitot tube icing in severe thunderstorm (see References 3-5) or
- Overstress separation of the airplane's vertical stabilizer and subsequent loss of control (see References 6-7) or
- A combination of both.

Continental-Colgan Flight 3407, a Bombardier Dash 8-Q400, which crashed on approach to Buffalo, N.Y., on Feb. 12, 2009, and Turkish Airlines Flight 1951, which crashed on approach to Amsterdam's Schiphol Airport 13 days later, were high-profile retrocursors. In both cases minor anomalies distracted the crews from the principal airmanship rule: "First fly the airplane." Crew distraction accidents have been a bane for decades (see References 8-11).

A third retrocursor was the FedEx MD-11 landing crash at Narita, Japan, on March 22, 2009, which duplicated a similar FedEx MD-11 accident at Newark, N.J., in 1997. A China Airlines MD-11 crash at Kai Tak in August 1999 exhibited similar operational behavior (see References 12-14).

Why haven't the lessons that should have been learned from earlier accidents been communicated well enough to the crews and internalized sufficiently to prevent the retrocursors?

Contemporary lessons-learned practices

Are there formal contemporary lessons learned "systems" and, if so, why don't they maximize learning from lessons generated by accidents?

Historically, investigators acquire, document, and report factual data in many forms and formats, by many diverse and often isolated systems. These data are used by investigators and analysts to piece together a description and explanation of what happened, usually in narratives or on pre-existing forms, using natural language. These accident data comprise the bases for cause-oriented conclusions from which findings and recommendations are derived. Causes, findings, and recommendations rarely specify the "lessons learned" from an investigation (see Reference 15). Analysts abstract, code, characterize, aggregate, or otherwise refine or condense the data. They are then "published": disseminated internally or made public in various news media, as databases, reports, articles, papers, books, stories, graphics, training materials, checklists, etc. Published data are stored in organizational files or databases for retrieval and use. They may also find their way eventually into revised procedures, standards, and regulations.

Dissemination practices vary but include electronic dissemination in computerized databases, e-mails, and Internet sites. Non-electronic dissemination may include hard-copy investigation reports, tables, checklists, on-the-job training, safety meetings, standardization, training sessions, codes or regulations, and books. Deriving lessons from the data depends on someone recognizing the value of the content and generating and communicating the lessons.

Reported investigation data may also be used for research, to develop lessons learned in the form of historical trends or statistical correlations, using statistical analyses or data mining techniques. Data are frequently abstracted or characterized to generate "taxonomies" of causes and causal factors referenced in investigation report databases, safety digests, and investigation software.

We analyzed contemporary lessons learning practices, focusing on how data are analyzed to isolate and describe the lessons that should be learned. Major inadequacies we observed include

- Authors variously define lessons as causes, cause factors, findings, conclusions, eecommendations, issues, statements, or scenarios in texts of narrative reports.
- Authors often obscure lesson data within excessive wordiness and jargon.
- Authors do not explicitly list lessons learned as such.
- Analysts rarely categorize investigation data to facilitate end-users' retrieval and use.
- Analysts assume that proposed changes alter system behavior favorably, without testing.
- Lessons are "pushed" to preestablished recipients, but must be "pulled" by other users.

What inadequacies of current lessons-learned practices have already been reported? Werner and Perry (see Reference 16) cited the following barriers to effectively capturing and applying lessons learned by investigators:

- Data are not routinely identified, collected, and shared across organizations and industries.
- Unsystematic lessons are too difficult to use because
  —there is too much material to search,
  —they are formatted differently in different reports, or
  —they're not readily available.
- Applications are unplanned and haphazard.
- "Taxonomy" categories obscure data searches.

We observed two categories of inhibitions to developing lessons learned within the investigation process itself. The more fundamental is a mindset of unquestioned acceptance of "how things have always been done" and can include

- archaic accident "causation" models,
- unwillingness to share investigation data,
- language barriers that obscure identification of relevant behaviors,
- data loss from software obsolescence and lack of standardization, and
- concerns for legal liability.

A secondary category frequently derives from the obstacles above and occurs at the levels of individual investigators and analysts. It includes missing data, biased scope and data selection, logic errors, misinterpretation or misrepresentation of observations, flawed assumptions, and premature conclusions during investigations. Each inhibits development of useful lessons.

Clarification of terms

Lessons learned are often considered to be new knowledge obtained from experience, applied to benefit future performance. The questions arise: knowledge about what? And how can we put it to beneficial use? We find it helpful to think of the new knowledge generated by investigations as clarification of what happened, and why it happened. That new knowledge can be applied to change behaviors of people, systems, or energies. This concept distinguishes between the lessons and the learning, identifying the tasks required of those documenting the lessons to describe and communicate them so that end-users can apply them to initiate desired behavioral changes.

What data are needed to develop lessons to be learned?

Mixed perceptions of the investigation data that need to be acquired and disseminated as lessons may be the greatest obstacle to learning. Accident causation and investigation models influence those perceptions. Current investigation goals do not prioritize information needed by end-users who initiate behavioral changes. Investigations focus on determining "causes": cause factors, multiple causes, "root" causes, and other easily labeled actions from which investigators and analysts infer lessons and propose corrections. Investigation report authors typically do not provide data in forms from which end-users can derive the behavioral changes they need to prevent recurrence. Instead, the "expert" investigating agencies select changes they deem desirable and direct them to target audiences of their choice in the form of recommendations.

Challenges to developing lessons learning systems

The challenges to lessons learning systems are to collect accurate mishap-based data and communicate them quickly and efficiently to end-users that can develop and implement changes.

The first challenge is to define the end-users of lessons from investigations and how they would use them. End-users are all entities that can change behaviors that led to an undesired outcome, or initiate new avoidance behaviors, in their operations, in objects or systems they design or operate, or in energies they manage. Current investigation data are designed to fulfill the needs of the

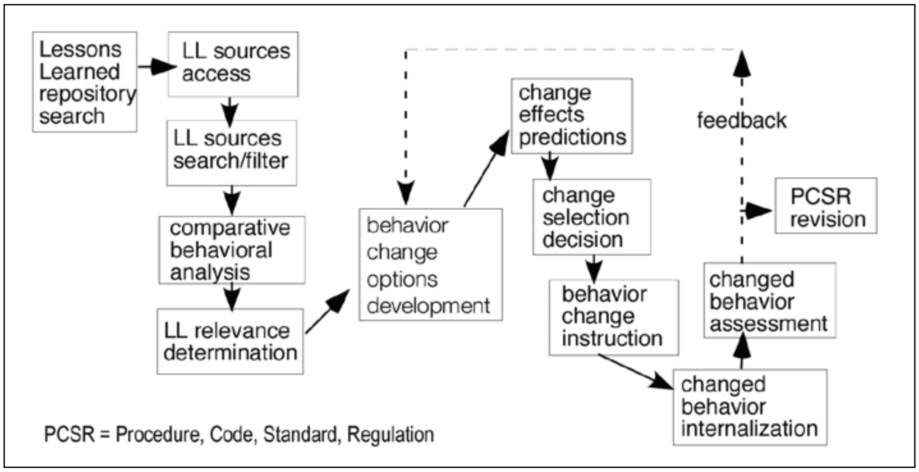

Figure 1. Users' components of lessons learning model.

agency conducting the investigation. The investigation community would better serve its prevention goal by devoting priority attention to fulfilling the lessons learning data needs of end-users that can apply that new knowledge to changing behaviors.

A second challenge is to systematize investigation data inputs and outputs by standardizing and applying scientific language. Common grammar, structure, and format for investigation input data should describe behaviors that constituted the mishap process thoroughly and objectively. Investigators must test behavioral data sequencing, coupling, and logic during investigations. That will ensure the identified, needed data will be developed and delivered to end-users in formats they can internalize readily and directly, and provide them with unambiguous reasons for changing the behaviors that produced the unwanted outcomes.

A third major challenge is to define the structure and content of the lessons learning system. It must satisfy end-users' needs and, at the same time, support machine documentation, processing, remote access, interoperability among users, and easy access. Its goal should be timely and efficient identification of the behavioral changes needed to effect the lessons that need to be learned, and their delivery to the people who need to learn them.

A lessons learning system

We developed a model of a comprehensive lessons *learning* system from investigations by tracking the functions and tasks required to achieve changed behaviors. The system begins with capturing the lessons-to-be-learned data during the accident process and ends with an archive of lessons and responses that have been tested and shown to produce effective results.

Users' components of the learning system model are shown in Figure 1. The model assumes that lessons learned are new knowledge developed by investigators about behaviors that interacted during the accident process. Each task can be decomposed further for specific applications.

Lessons learning system attributes from users' perspectives

What should users expect from a lessons learning system (LLS)? LLS users deal with dynamic processes. LLS documentation must be behaviorally consistent with dynamic processes to enable comparing behavior sets, defining alternative changes to behavioral relationships, and predicting effects that changes might introduce. The system should enable translating LLS response options into some form of change management analysis and into instructions to incorporate the changed behavior in the targeted person, object, energy, or process. Therefore, LLS must describe behavioral interactions among people, objects and energies, rather than linear "causes" or abstracted "factors." Ideal LLS attributes include

- open to multiple change options.
- inclusive of context identification.
- accessible expeditiously to all potential users.
- backward compatibility with legacy data repositories.
- minimize elapsed time (latency) between the occurrence that generates data for LLS, and when the lesson becomes available to end-users.[1]
- maximize "signal to noise" ratio, i.e., maximizing relevant content.
- enhanced determination of relevance.
- enhanced assimilability.
- scalability: the ability to increase data quantity without sacrificing quality.
- cost sensitivity: the value of the system in terms of results it produces.
- improved acceptance, and more actions initiated, by end-users.
- performance metrics for behavioral changes.
- timely repository updating.

Lessons learning system attributes from system developers' perspectives

From a developer's perspective, shown in Figure 2, investigation components of LLS should support development of lessons-to-be-learned source data with such attributes as

- Establish an input-output framework for defining what happened

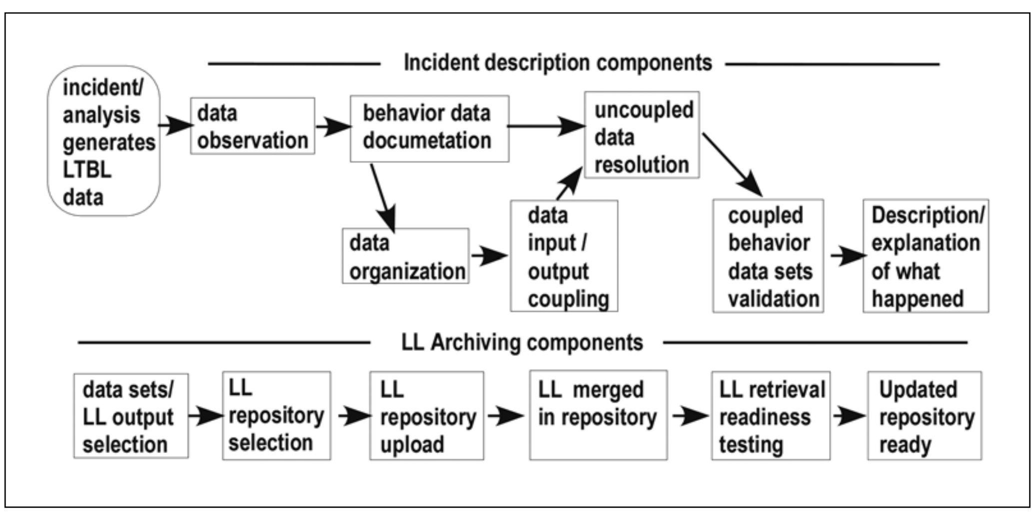

Figure 2. Developers' components of lessons learning model.

by LLS data sets that describe behaviors in non-judgmental and logically verifiable terms.

- Establish investigation goals to provide lessons that can change future behaviors.
- Focus on behavior data acquisition and processing.
- Specify a structure for input data documentation that ensures data consistency and economy and facilitates data coupling and support for documenting output LLS.
- Machine supportable input data management, display, and expansion to reduce latency.
- Objective quality assurance and validation processes.

Lessons learning system documentation component attributes

LLS documentation derived from investigation descriptions must fulfill end-users' needs. System attributes should include

- Requirements that behavioral data outputs provide context, minimize interpretive and analytical workload, maximize signal-to-noise ratio, and reduce latency.
- Provisions for machine processing support, interoperability, and repository uploading capabilities to accelerate documenting and distributing lessons to all collections.
- Establish accessible Internet LLS output data libraries and end-user notification to support both "push" and "pull" data distribution and minimize latency.
- Easy repository access, with search and filter capability to minimize end-user access time, cost, and workloads.
- Objective verification and validation to ensure quality before dissemination.
- Provisions to modify and update collected data with new knowledge.

Other observations

During the study of lessons learned processes we noted two other significant observations:

- Special investigating bodies appointed to inquire into specific accidents often address lessons learned explicitly in their reports (see References 18-20). Yet the reports we surveyed by traditional government investigation bodies lack a discrete section addressing, documenting, or summarizing the lessons found during the investigation. No standardized guidance exists for doing so. For example, ICAO Annex 13 does not define or otherwise mention lessons learned. Lack of standardized methodology for reporting "lessons" burdens prospective end-users by requiring them to search and interpret voluminous data with little assurance of finding what they need to initiate changed behaviors.
- LLS requires designers to make strategic choices about investigation process frameworks, purposes, scope, and data structures; LLS content, form and language; and appropriate choices of repositories, distribution, updating and metrics. Traditional (or inadvertent) strategic system design choices have adversely affected the utility of current LLS processes, operation, and performance.

Conclusions

Contemporary investigation-based LLS has not prevented recurrence of accidents from known behaviors that produced undesired outcomes. Their primary weakness lies in neglecting the knowledge requirements of users capable of changing those behaviors. Current reports are too often inconsistent, ambiguous, and vague. Investigating agencies should design LLS to identify and report all the lessons that can be learned from each mishap, record them explicitly for ready access and retrieval, oversee their application in which they can contribute to avoiding retrocursors, and measure the results. The first steps needed to improve lessons learning practices are

- redesigning the form and substance of lessons-to-be-learned source data to improve their usefulness for users, and
- redefining investigation data product specifications to require that lessons learned be an explicit documented output of the investigation processes. ◆

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Endnote

1. Boyd's "OODA Loop" concept (Reference 17) encourages the strategy of responding to situational feedback to effect immediate changes by bypassing administrative process, i.e., prioritizing the application of new LLS knowledge to change behavior, improve operational efficiency, and avoid retrocursors.

Using the Best Cost Analysis for Effective Safety Recommendations

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

Dr. Simon Mitchell *has worked in the aviation industry for more 20 years, a career that includes 5,400 professional helicopter flying hours, combined with doctoral research into accident cost analysis and the economics of safety. As a professional pilot, he has experience in all the key helicopter industry sectors: military flying, in offshore oil support, as a police pilot, and as a corporate pilot and safety manager. He is a visiting fellow with the Cranfield University Safety and Accident Investigation Centre and is course director for its safety management professional and academic course. He lectures on the framework of Safety Management Systems, integrating safety management within business management, value of safety management, accident cost analysis, regulatory and market safety controls, safety data and analysis. His current role with RTI Ltd is as aviation director, which includes oversight of business concerned with issues of safety risk management, fault, regulation, and cost-benefit.*

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 U.K. Air Accidents Investigation Branch.*

Abstract

This paper summarizes research to examine accident cost analysis and associated cost reduction measures. The evidence supports the value of a common methodology utilized by the legal profession, namely: primary, secondary, and tertiary cost categorization. This methodology associates costs with cost drivers in clearer detail, and consequently it is a more effective way to structure the analysis. It will highlight priorities and target safety recommendations to appropriate stakeholders better than the more simplistic "direct" and "indirect" cost classification (as advocated by International Civil Aviation Organization [ICAO]). The legal profession's methodology, as described by the Hon. Guido Calabresi (U. S. Court of Appeals for the Second Circuit) in his text *The Cost of Accidents,* 1970, results in an easily understood relationship between costs and technological remedy, costs and regulatory remedy, and costs and investigative remedy. This paper illustrates with general principles how this methodology can be adopted effectively by aviation accident investigators, without any need for sophisticated financial skills, and how it can greatly enhance an investigator's ability to frame compelling, well-argued, and fully justified safety recommendations.

Introduction

Accident investigators recommendations 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 paper is concerned with using cost information about accidents to aid decision-makers who seek to avoid or mitigate future costs in other words, putting emotive discussions to one side, 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 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 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.

Para 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 Mitchell's doctoral thesis (see Reference 2), 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 and 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.

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 & Damage Claims	Indirect	Secondary & Tertiary
Fines & Citations	Indirect	Primary & 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.

While the list of cost items shown is obviously not exhaustive, it is sufficiently indicative and also it 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 the purposes of this paper, it will be assumed 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 subgoals (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 classification 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 results in costs). These costs range from damage to equipment, 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" (see Reference 4) 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" (see Reference 5), 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).

"It should be noted in advance that these subgoals [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."* (Calabresi, 1970, page 29)

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.

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.

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, and 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. 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 towards 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 of this paper have compared these two systems in great detail and are of the opinion that the accident cost classification system based on Calabresi's work (see Reference 4), modified by Shavell (see Reference 5), 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. ◆

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Safety: A Function of Leadership

By Gary D. Braman; System Safety Engineer; Sikorsky Aircraft Corporation, Huntsville, Ala., USA

Gary Braman is a system safety engineer with Sikorsky Aircraft Corporation in Huntsville, Ala. He is a retired master Army aviator with more than 25 years in the aviation and safety professions. While on active duty, he served in varying positions of responsibility as an aviation safety officer, from the flight detachment level through the Department of the Army level, including 6 years at the United States Army Safety Center (USASC). While at the USASC, he served as a U.S. Army accident investigator and as a primary instructor for the U.S. Army Aviation Safety Officer Course. He has a master of aeronautical science (MAS) degree in aviation/aerospace management from Embry-Riddle Aeronautical University (ERAU) and a master of science (MS) degree in industrial engineering technology and safety management from Texas A&M University. Braman is a certified safety professional (CSP) and holds certifications in hazard control management; environmental auditing in health and safety; and environmental, safety, and health management. He is an assistant adjunct professor for ERAU in Huntsville, Ala., certified to teach all safety-related courses including graduate- and undergraduate-level accident investigation, human factors, and system safety courses. Braman is active in various professional organizations, including the International Society of Air Safety Investigators (ISASI), the American Society of Safety Engineers (ASSE), and the System Safety Society.

Abstract

This paper explores how top management and leaders have reduced accident rates by embracing the philosophy that *"safety is a function of leadership."* It will also illustrate how accidents have occurred due to a lack of leadership. The safety is a function of leadership philosophy is effective in both military and civilian organizations and includes both aviation and ground operations. To illustrate these points, the paper examines the "Five Point Safety Philosophy" of General John A. Wickham, instituted during his tenure as the Chief of Staff of the Army (1983-1987). During this time, General Wickham saw that many unnecessary accidents were occurring during combat training and numerous soldiers were dying needlessly. The Five Point Safety Philosophy was part of his "Safe Army Now Program," which was initiated to assist unit commanders in conducting realistic and safe combat training. Additionally, since 1999, the National Safety Council has presented its annual Green Cross for Safety Medal to organizations and their leaders for their outstanding achievements in safety and health. To be considered for the award, an organization and its leadership must demonstrate a superior record in advancing safety and health practices consistent with the mission of the National Safety Council. The 2009 recipients include a mixture of company leaders in the luxury transportation, utilities, construction, and nuclear power industries. The paper will also illustrate through example how a lack of leadership results in unnecessary catastrophic and fatal accidents. These examples provide overwhelming evidence to support the conclusion that safety is, and always will be, a function of leadership, and safety leadership is extremely effective in the prevention of accidents. It also supports the conclusion that only when organizational management and leadership embrace safety as their ultimate responsibility, as managers and leaders, will unnecessary accidents be prevented.

Introduction

On Feb. 12, 2001, two UH-60L Blackhawk helicopters collided in flight while executing a 180 degree turn while flying in formation with two other aircraft. The aircraft were participating in a night vision goggle, multi-ship air assault. The flight of aircraft was executing a 180-degree right turn to final approach to a tactical landing zone (LZ) when chalk 4, sling loading an M998 HMMWV, collided in midair with the lead aircraft. Both aircraft crashed and were destroyed. All six occupants on board chalk 4 (trail) were fatally injured, and 5 of the 11 personnel on board the lead aircraft were injured (see Reference 1).

The accident occurred due to inadequate mission planning on the part of unit leaders. During the planning of the mission, the unit leaders made numerous errors, with the most significant being the requirement to have the flight of four aircraft make a 180-degree turn to their landing zone while sling loading M998 HMMVs. The mission planners required the four UH-60L aircraft to execute a 180-degree continuous right turn to final in a compressed maneuver area. Though the investigation did not determine exactly why the aircraft collided, it is known that if alternative routing had been determined, it is very likely this accident would not have occurred and the six personnel fatally injured on the lead aircraft would be alive today. If the organization's leaders had adequately planned this mission, it is highly likely it would not have occurred, highlighting the fact that *safety is a function of leadership.*

Safety and leadership defined

During an accident investigation, three specific areas are always investigated to determine the cause of the mishap. These include human error, materiel factors, and environmental factors. If it was determined that a human error occurred, it can be further investigated to determine the root cause. Human errors have five specific root causes as defined by the U.S. Army (see Reference 2):

- Training failure—formal training, experience, or on-the-job training is insufficient in content and amount.
- Standards/procedures failure—standards and procedures are not clear or not practical or standards and procedures do not exist.
- Support failure—shortcomings in type, capability, amount, or condition of equipment, supplies, services, facilities, and number and type of personnel.
- Individual failure—individual knows and is trained to the standard but elects not to follow the standard (self-discipline—mistake due to own personal factors).
- Leadership failure—direct, unit command, or higher command

supervision not ready, willing, or able to enforce known standards.

Leadership can be defined as the ability or capacity of one individual to influence the actions of others to accomplish a specific task, objective, or goal. Leaders can be those people in positions of specific authority such as a supervisor or manager, or it could be someone who is a leader by virtue of position with no specific authority. These people include flight instructors, aircraft captains, or safety professionals. Army leadership refers to officers, non-commissioned officers (NCO), senior executive service (SES) officials, and government service (GS) employees designated, authorized, held responsible, and accountable by the Army to make decisions at various levels of the Army involving execution of the Army's mission. An inherent responsibility of every leader is to accomplish the task, goal, or objective in a safe manner.

Safety is defined as freedom from those conditions that can cause injury, death, occupational illness, or damage to, or loss of, equipment or property (see Reference 3). It is now obvious how the leaders failed in the accident sequence described in the introduction. Had the leaders been involved, taken appropriate action, and adequately planned the mission of the Blackhawk helicopters ensuring the safety of the crews and their aircraft, this accident would have never happened. (This was only a training mission, and taking this type of risk was not necessary nor was it required to train the aircraft crews in performing this task.

Leadership failures

As a former Army accident investigator, I could provide literally hundreds of examples highlighting the fact that safety is a function of leadership. However, the following two examples truly exemplify the phrase *safety is a function of leadership.*

Oh Ye of Little Faith: During my time in the Army as an aviation safety officer, I was trained to be on the lookout for high-risk aviators or what we used to call "cowboys." Cowboys are not identifiable by age, gender, race, rank, or position and can be anyone. They are sometimes praised as heroes because they accomplished a mission under extremely difficult circumstances and at very high risk. Their behavior is known to everyone in the organization. including the chain of command, though no action is undertaken to stop it. They can be the best or the worst officer in your organization. Their behavior can be very obvious or very discreet. They don't like doing things by the book and don't understand why they should. They become defensive when confronted and will always have an excuse for their actions.

I served on an accident investigation board investigating the crash of an AH-64 Apache in January 1997. Shortly after arriving at the scene of the accident, we were handed the tape from the aircraft's video recorder. After viewing the tape, I knew we were dealing with cowboys. An accident had been inevitable during this flight; it wasn't a question of "IF" an accident was going to happen, it was only a matter of "WHEN" (see Reference 4).

The mission was a single-ship, day aircrew training manual (ATM) training flight for an officer who had not flown much but was scheduled to deploy on a Joint Readiness Training Center rotation. The training was to include high- and low-level reconnaissance, low-level flight, and nap-of-the-earth flight with target-engagement operations. The crew was briefed to conduct the flight in the local training area utilizing several different sectors and transition corridors.

As part of preflight planning, the crew checked the weather, computed aircraft performance data, and assessed the risks associated with the mission. Additionally, it conducted all mission and crew briefings. The crew then filed the flight plan and completed the preflight inspection of the Apache. The time was about 1400 when they took off. The pilot-in-command (PC), who was also a unit IP, was in the backseat on the controls, and the copilot was in the front seat. They conducted ATM training consisting of low-level and NOE operations in several different training areas. They also practiced multiple target engagements and high- and low-recon of landing zones. This training was completely documented on the aircraft's videotape. The video also showed the PC operating the aircraft as low as 3 feet above ground level (AGL) at 26 knots between trees and wires beside common-use roads. At one point, the copilot was heard to say, "Yeeeeeee-haaaaaaaa," as the PC completed a return-to-target maneuver.

The crew continued the flight along a common-use roadway until arriving at one of the large drop zones scattered around the reservation. The PC turned the aircraft left to a heading of 320 degrees toward a stand of trees. As the aircraft approached the trees, the PC noted a gap in the trees and asked the copilot, "Do you think we can make it between there?" The copilot answered, "Nope." The PC then remarked, "Sure we can. Look how big it is. Oh, ye of little faith. Look how big that is."

At 1532, immediately after the PC's remarks, the No. 4 main rotor blade struck a 2½-inch diameter limb, breaking off an 8½-inch piece of the blade. The Nos. 2 and 3 main rotor blades also struck the tree. The aircraft shook violently, but the aircrew was able to land in an open field unassisted. The aircraft was at 16 feet AGL and 76 knots when it struck the tree, resulting in more than $1 million in damage to the aircraft.

Approximately one year later while serving in Korea, an individual approached me during a social event and began talking to me. Though I knew his face, I couldn't remember his name. After telling me his name, he told me I knew him from the "Oh Ye of Little Faith" accident. He was the battalion standardization officer. He told me he owed me an apology. During his interview that was part of the accident investigation, he stated he lied to us as had several others. He said this was not the first time this pilot had acted in this manner, and it had occurred again after the investigation was complete. I asked him why he or anyone else would protect this individual knowing he could kill not only himself but others. I got no response.

The Grenade: In August 1996, an infantry battalion's scout platoon had occupied a range in the local training area in preparation for numerous training events that were to take place over a period of several days. Training on the first day consisted of day and night, dry and blank firing, as well as live-fire operations in preparation for the next day's training. The training was conducted without incident. The second day's training consisted of a hand grenade range and a fast rope live-fire exercise (see Reference 5).

Early in the morning of the second day, the lieutenant platoon leader, who was also the range officer-in-charge (OIC), was informed that another unit was also scheduled to use the same range that day. In an attempt to expedite the training, the lieutenant picked up four M67 fragmentation grenades from the ammo supply point on his way to conduct his leader's recon for the fast rope live-fire exercise. From there, he would go directly to the grenade range. As he headed toward the recon area, he attempted to secure the grenades in the four grenade pouches located on his two ammo pouches. He properly secured three of the four. The fourth was only secured to the pouch by the grenade pouch strap that he had placed through the grenade pin. Upon completion of the recon, he noticed one of the grenades was missing. The grenade pin was still hanging on the grenade pouch strap.

The lieutenant immediately went to find the grenade. He searched for the grenade for two hours without success. He notified his platoon sergeant, also the range safety officer (RSO), and told him of the missing grenade. He instructed the platoon sergeant to continue training. The battalion command sergeant major, who was inspecting training on the range, was informed of the missing grenade and called a cease fire halting all training. He notified range control and the chain of command. Early that afternoon, Explosive Ordnance Disposal (EOD) personnel arrived on the scene. After viewing the terrain and vegetation where the grenade had been lost, and knowing that the grenade had no safety pin, EOD personnel assessed the risk of searching for the grenade as "extremely high." The EOD detachment commander would not allow his people to search for the grenade or assist the unit in searching for the grenade.

The local range regulation stated that the unit was to cordon off the area, mark it as an impact area, and the area would be burned in the fall. These actions had been completed under the supervision of range control when the word came from the division commander that the unit was to find the grenade. The division commander had not been informed that the grenade was missing the safety pin.

The following day (Day 2), the unit initially attempted to find the grenade by cordoning off the area where it was suspected that the lieutenant had lost it. The area was then divided into lanes wide enough for eight soldiers. Standing side by side, the soldiers would slowly walk down the lane, carefully moving each branch and twig, looking for the grenade. This proved to be unsuccessful. Later that day, word came from division headquarters that the general had been informed the grenade had no pin and had told the unit chain of command not to use soldiers to find the grenade but to use the engineers and EOD to locate the grenade.

The following morning (Day 3), an engineer unit attempted to find the grenade using minesweepers. The mine sweeper (basically a metal detector) is employed by swinging it back and forth over low-cut or barren terrain. The vegetation where the grenade was lost is more than 10 feet high and so thick a human can hardly walk through it. Due to the vegetation, the mine sweepers could not be used. In an attempt to assist in the employment of the mine sweepers, the infantry soldiers were told to cut down the vegetation. They put on their fragmentation vests and Kevlar helmets, were issued axes, machetes, sickles, and scythes, and went back in the area to cut the vegetation. The operation continued uneventfully for the rest of the day.

Early on the morning of the fourth day, the brigade commander arrived at the range and briefed the soldiers. Part of his briefing included how to properly cut the vegetation in order to locate the grenade. After he briefed the soldiers, he departed the range and the soldiers again began cutting the vegetation. Ten minutes after the brigade commander left the range, the grenade exploded.

At the moment of detonation, the battalion commander, the platoon leader, and platoon sergeant were huddled together discussing the situation. A young specialist was walking down the hill toward them with an axe. The specialist did not have his fragmentation vest properly closed and a small grenade fragment pierced his heart killing him instantly. The battalion commander's left foot and lower left leg were so badly injured that his leg had to be amputated below the knee. The lieutenant and staff sergeant received multiple shrapnel wounds, and seven other soldiers who were within 12 feet of the blast also received shrapnel injuries.

As you read the accident scenario, you should be able to identify the leadership failures with many questions coming to mind such as "How could anyone let this happen?" or "Why were soldiers' lives risked to find a grenade that did not have a pin in it?"

The Five Point Safety Philosophy

In 1983, President Ronald Reagan appointed General John A. Wickham, Jr. as chief of staff of the Army. During his tenure, which ended in 1987 when he retired, he was dedicated to safety and accident prevention. He had seen too many soldiers were dying needlessly in training accidents.

In December 1986, the United States Army Safety Center (USASC) (now the United States Army Combat Readiness/Safety Center–USACRC/Safety Center) published a document entitled "Safety Army Now." The document was a roadmap for unit commanders to use when conducting training, ensuring it can be both realistic and safe. The document reflects General Wickham's commitment to safety in his Five Point Safety Philosophy. These points are listed below (see Reference 6).

- Nothing we do in peacetime warrants the unnecessary risk of life and equipment—You cannot say that "we are going to do this in the name of realism," if doing it exposes your people or equipment to unnecessary risk. We must be alert for ways to improve the efficiency, effectiveness, and safety of all our operations. This can be modified to fit both the military and civilian worlds. Nothing we do warrants the unnecessary risk of life and equipment.
- Commanders are safety officers—This is the message I give my commanders: "You must put yourself out as the safety officer." That doesn't mean that others are not responsible and helpful in their roles, but unless the commander is involved, safety isn't going to happen. Supervisors and managers are safety officers. They must be involved to fulfill their role and responsibilities as leaders.
- Instill in soldiers a sixth sense of safety—We have to develop that kind of sixth sense about safety within the Army so that soldiers and leaders are conscious of unsafe acts that are about to happen, so that they see the potential for tragedy and avoid it. Civilian supervisors and managers can also instill this sixth sense of safety in their employees.
- Fix accountability—Accountability must be fixed and people must develop a sense of responsibility to accept it. When accidents are caused by someone's clear negligence, then some concrete action must be taken. That person must be penalized.
- Safety officials must be proactive and aggressive—You must be personally involved in the activities, the training activities, the on- and off-duty activities, of your unit in your role as safety officer.

These five points are very basic, simple, easy-to-remember, and quite effective. They fit both military and civilian activities. The key point in his philosophy is the first one: "Nothing we do in peacetime warrants unnecessary risk of life or equipment." The total disregard for this first, and foremost, point is illustrated only too well in the previous accident scenarios.

Leadership successes

Green Cross for Safety Medal: Since 1991, the National Safety Council annually awards the Green Cross Medal for Safety. The award recognizes organizations and their leaders for outstanding achievements in safety and health, and for responsible citizenship. To be considered for the Green Cross for Safety Medal, an organization and its leadership must demonstrate a superior record in advancing safety and health practices consistent with the mission of the National Safety Council. The winner of the 2009 Green Cross for Safety Medal was Moir Lockhead, Chief Executive FirstGroup PLC, Aberdeen, Scotland/Cincinnati, Ohio. Lockhead's corporation employs 137,000 people worldwide. The following leaders were recognized by the National Safety Council as their 2009 CEO's who get it (see Reference 7).

- Robert Bellagramba, president, CEO and CFO, Concorde Limousine Inc. (a luxury transportation service company), Freehold N.J.
- Larry C. Bryant, commissioner, South Caroline Vocational Rehabilitation Department (a state government agency), West Columbia, S.C.
- Dan Fulton, president and CEO, Weyerhauser Co. (a manufacturing, distribution, and sales of forest products company), Federal Way, Wash.
- James H. Miller, chairman, president, and CEO, PPL Corp. (an energy company), Allentown, Pa.
- Davis Mullholland, president and CEO, CCI Mechanical Inc. (a design, installation, and maintenance of mechanical systems company), Salt Lake City, UT.
- George H. Rogers, III, president and CEO, RQ Construction, Inc. (full-service construction company), San Diego, Calif.
- Vic Staffieri, chairman, CEO, and president, E. On U.S. (a diversified energy services company), Louisville, Ky.
- Capt. Neil C. Stubits, Indian Head Division, Naval Surface Warfare Center, (U.S. Navy research, development, and test facility), Indian Head, Md.
- Andy Studdert, chairman and CEO, NES Rentals (an aerial equipment rental company), Chicago, Ill.
- Timothy J. Whitener, CEO, LUWA Inc. (an HVAC specialty contractor), Winston-Salem, N.C.

These CEOs run a variety of different companies, with a varying number of employees, and are located in all corners of the company. Though they are of varying sizes and in various locations they have a lot in common. Each of these individuals was asked a series of questions with the first one being "Why is safety a core value at your company?" The recurring theme was people, be they employees or customers. Additionally, safety was not seen as an impediment to doing business, but an integral part of their business. Without safety, they could not succeed and their companies or organizations would not be successful.

U.S. Army: In December 1986, the then United States Army Safety Center (USASC) published the results of a study that was conducted to determine what makes the difference between a unit with no accidents and a unit with accidents. The USASC surveyed three battalion sized units that had historically excellent safety records. They analyzed the following aspects of these organizations (see Reference 8):

- Management—The management aspects analyzed included the qualifications of the aviation unit commander, performance criteria established by the commander, pilot-in-command appointment process, priority given to training; and support received from higher headquarters.
- Operations—The survey focused on flight operations being conducted *by the book*.
- Maintenance—Maintenance activities were analyzed to determine if they were performed *by the book*; determine the strength of NCO leadership involved in maintenance operations; and maintenance quality control.
- Training—The review of training was very in-depth. It included reviewing and analyzing the emphasis placed on training, aviator self-discipline, action taken against violators of proper flight discipline, mission planning, crew selection, enforcement of the safety program by the flight instructors, aviator proficiency training, and NCO training.
- Accident prevention program—The unit accident prevention programs were reviewed and analyzed to determine if aviation safety officers were involved and supported by the unit chain of command, if safety surveys were conducted and results acted on, and the management of the safety program.
- Aviation medicine—This topic dealt primarily with flight surgeons, their support of the units, their credibility, their involvement in the unit safety program, and the use of the flight surgeons.

The analysis of these areas of aviation units highlights the fact that involvement by unit leaders is absolutely necessary to prevent accidents. These unit leaders not only include the unit commander and his/her non-commissioned officers (NCO), but the unit's aviation safety officer (ASO), the maintenance officer, and the flight instructors. Leaders not only are those individuals in positions of authority, such as CEOs, supervisors, managers, or unit commanders and NCOs, but also those individuals who are leaders by virtue of their position in an organization. They are also the individuals who set the examples of conduct for subordinates in any unit or organization.

Conclusions

Though only a small number of leadership failures and successes were discussed, it is readily apparent that safety is, and will always, be a function of leadership. It can be applied to civilian industry, military units, and government agencies regardless of the number of employees or location. Safety works when the CEO's get it! ◆

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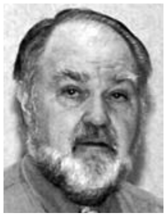
A Review of Fly-by-Wire Accidents

By Dr. R.L. (Dick) Newman, Seattle, Wash., and A.A. (Tony) Lambregts,
Chief Scientist-Advanced Controls, FAA, Renton, Wash., USA



__Dick Newman__ recently retired from the FAA where he was an aerospace engineer in the Transport Airplane Directorate. Prior to joining the FAA, Dr. Newman was an associate professor of safety science at Embry-Riddle Aeronautical University in Prescott, Ariz. Prior to that he was a consulting engineer, a test pilot, and an airline pilot.

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.

Summary

The history of fly-by-wire (FBW) airplanes will be reviewed with a emphasis on the certification requirements found in Part 25. We will examine the service history of civil FBW airplanes, using several databases for FBW accidents and serious incidents.[1] These accidents and incidents will be screened to exclude those with no flight control involvement. Three types of incidents will be found and their causes will be discussed.

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
MMO—Maximum operating Mach
PF—Pilot flying
PIO—Pilot induced oscillation
PNF—Pilot not flying
TCAS—Traffic Advisory and Collision Avoidance System

Introduction

In October 2008, Qantas Flight 072 experienced a flight control malfunction flying between Singapore and Perth. The airplane pitched over abruptly seriously injuring fourteen passengers and cabin crew. The flight diverted to an Australian Air Force base and these injured were flown by helicopter to hospital (see Reference 1).

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 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 man-power 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. By programming the flight control computers to compensate for the less basic airframe stability when the operational center of gravity is moved aft, the airplane drag can be reduced and the maneuverability can be increased. In transport airplanes, such as the Airbus A320 or Boeing 777, this 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."[2] 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, or Embraer—have employed special conditions for the flight control system.

There are currently 10 civil airplane designs with FBW flight controls.[3] 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: Civil Transport FBW Models

Manufacturer	Certified Models	Proposed Models
Airbus	A320, A330, A340, A380	A-350
Boeing	777	787
Bombardier		C-series
Dassault	7X	SMS
Embraer	E-170, E-190	
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	~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	

Table I lists the current and proposed civil airplane FBW aircraft. The next section outlines the methodology used to examine the service history.

Method

One of the problems with examining safety problems with extremely safe systems is the lack of many examples. We only found 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 (see References 2, 3, 4, 5). We also used two private databases: the Aviation Safety Network and Flight Simulation Systems databases (see References 6 and 7). 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 inservice 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 A330/340 and E-170/190. 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 (in Appendix) 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)[4] 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 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

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)	

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

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 officers. 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.

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 (see Reference 8) (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 (MMO+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 during 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 (see Reference 9) (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 (see Reference 10) (case l).

"Backwards" sidestick: On March 20, 2001, an A320 rolled left at lift-off. 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 (see Reference 11) (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 (see Reference 12) (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 (see Reference 13) (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).

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 paper. Also 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 study and careful assessment of the consequences of dual inputs. At this 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 (see Reference 14). 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.

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 Alliquippe) 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 currently 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 per-

Appendix

Table A: Accident Listing Civil FBW in Service Incidents

Case	Date	Model	Registration	Where	Flight Phase	Description
(a)	26Jun88	A-320	F-GFKC	LFGB	Manuevering	Collision with Terrain
(b)	14Feb90	A-320	VT-EPN	VOBG	Landing	Collision with Terrain
(c)	26Aug93	A-320	G-KMAM	EGKK	Initial climb	Uncommanded Bank
(d)	27Apr95	A-320	N-331NW	KDCA	Approach	Pilot Induced Oscillation (PIO)
(e)	28Apr95	A-320	N-331NW	KMSP	Climb	Uncommanded Bank
(f)	18Mar96	A-320	N-340NW	KDTW	Cruise	Uncommanded Pitch
(g)	14Jun96	A-320	N-347NW	KBOS	Climb	Uncommanded Pitch
(h)	21Jun96	A-340	D-AIBE	KDFW	Climb	Abrupt Maneuver
(i)	14Aug98	A-320	G-MIDA	EIDW	Landing flare	Abrupt Maneuver
(j)	5Nov99	B-777	N-784UA	EGLL	Rotation	Abrupt Maneuver
(k)	2Oct00	A-340	TC-JDN	N Atlantic	Cruise	Uncommanded Pitch
(l)	7Feb01	A-320	EC-HKJ	LEBB	Landing	Abrupt Maneuver
(m)	17Mar01	A-320	N-357NW	KDTW	Rotation	Pilot Induced Oscillation (PIO)
(n)	20Mar01	A-320	D-AIPW	EDFF	Initial climb	Uncommanded Bank
(o)	15Jun01	A-320	N-561AW	KSAN	Maneuvering	Abrupt Maneuver
(p)	9Aug01	A-320	G-EUPV	EGLL	Approach	FCS Mode Reversion
(q)	14Jun02	A-330	C-GHLM	EDDF	Approach	Uncommanded Pitch
(r)	7Dec02	A-320	C-GIUF	CYYZ	Approach	Pilot Induced Oscillation (PIO)
(s)	7Dec02	A-320	C-GJVX	CYYZ	Approach	Pilot Induced Oscillation (PIO)
(t)	16Jun03	A-320	C-GTDK	EGGD	Landing flare	Abrupt Maneuver
(u)	15Apr04	A-320	G-TTOA	LEMG	Descent	Abrupt Maneuver
(v)	25Jun05	A-320	I-BIKE	EGLL	Approach	FCS Mode Reversion
(w)	1Aug05	B-777	9M-MRG	YPPH	Climb	Uncommanded Pitch
(x)	3May06	A-320	EK-32009	URSS	Missed appr	Collision with Terrain
(y)	23Oct06	A-320	N-924FR	KDEN	Landing flare	Uncommanded Pitch
(z)	27Mar07	E-170	HZ-AEN	OERK	Descent	Uncommanded Pitch
(aa)	7Oct08	A-330	VH-QPA	YPLM	Cruise	Uncommanded Pitch

sonnel 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 (see Reference 15)—*not one was a FBW airplane.* ◆

Endnotes

1. We will use the term incident to describe the events. It seems too cumbersome to use "accidents and serious incident" repeatedly throughout the text.
2. Rogers Smith (NASA Dryden Flight Research Center), May 2004.
3. The Concorde's type certificate has been cancelled, and it is not considered in this paper.
4. Lower case italic letters, such as (a), refer to specific accidents listed in the Appendix.

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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

Dr. Eric Robert Savage is an assistant professor of safety science at Embry-Riddle Aeronautical University in Prescott, Ariz. He's held an assistant professor position at the University of Dubuque in the Aviation Department, and a visiting assistant professor position at Southern Illinois University Carbondale in the Aviation Management and Flight Department. He received his B.S., M.S., and Ph.D. from Purdue University and his MBA from Southern Illinois University Carbondale. Dr. Savage worked for the Boeing Company both as an estimating and pricing analyst within business management and a human factors design engineer within flight operations and systems engineering. Dr. Savage has significant experience co-engineering platform cockpits and co-managing international programs for the Boeing Company's F/A-18, F-15, T-45, T-38, and AV-8B aircraft programs. He is a private pilot, instrument ground instructor, a trained air safety investigator, and a trained air traffic controller. He is a member of the Human Factors and Ergonomics Society, International Society of Air Safety Investigators, University Aviation Association, American Management Association, and Society of Automotive Engineers. He has served as a contributing editor for the Journal of Professional Aviation Training and Testing Research, *a new textbook in engineering psychology, and is currently writing a new textbook in human factors engineering. Dr. Savage's current research topics are emergency evacuation, passenger and flight attendant behaviors, and modeling the cost of aberrant behaviors.*

***Erich Skoor** photo and bio are not available*

Abstract

The certification of transport-category aircraft requires an emergency evacuation demonstration mandated in both FAR Part(s) 25[1] and 121[2]. There are many constraints on the demonstration, including gender, age, exit availability, and time. There are no provisions in the regulations concerning use of simulation for emergency egress; yet, simulation is widely used in design considerations for buildings, roads, manufacturing processes, and even aircraft evacuations. Muir et. al.[3] has studied passenger behaviors within emergency evacuation of transport category aircraft and suggested the use of simulation as an alternative to demonstrations, to better understand the impacts of variability in emergency egress situations. Moreover, Galea[4], Ceruti and Manzini[5], Xue and Bloebaum[6], Parks and Ostrand[7], and Schroeder[8] have studied simulation of emergency evacuation to create valid models with finite parameters to better understand the impacts of variability in egress environments.

The simulation approach adopted here involved the development of models with varying levels of detail, such as movement durations through the sequential evacuation stages-exit seat, exit aisle, exit door, and exit slide. These times were modeled by the gamma and lognormal statistical distributions with parameters estimated from observations and data related to human movement in constrained evacuation situations. Constraints were placed on the activities to simulate blockages at various stages of the evacuation. These constraints were intended to represent handicapped passengers or "kin" behaviors in which groups of passengers attempt to stick together. The results of the preliminary simulations indicated the viability and validity of the approach and showed the expected effects of passenger movements and delays. More extensive investigations, planned over the coming months, will explore blockage types and effects, and discounting models of passenger and flight attendant behaviors.

Introduction

Aircraft accidents are relatively rare events. However, the context of high (but survivable) impact forces, volatile fuels, ignition sources, and flammable materials is such that successful evacuation is a very time critical issue[9]. There are examples of successful evacuation of large aircraft in a very short time—both from demonstrations and from actual accidents (e.g., the Toronto runway excursion accident involving an Air France A340 in August 2005; and the recent British Airways B-777 in London), with minimal casualties. There are also records of unsuccessful evacuations (e.g., the Air Canada DC-9 at Cincinnati in 1983 in which 23 of 46 people died due to the fire, and the British Airtours B-737 at Manchester, England, in 1985 in which 55 people perished in an aircraft that never left the ground). New airplanes are being designed with greatly increased capacity, but the time available for evacuation is unlikely to increase. Potential solutions to this problem are an increase in the capacity of the escape routes together with improved procedures and training. Discrete event simulation approaches will provide important contributions to these designs.

Background

The requirements for emergency evacuation demonstrations by operators were first established in Part 121.29 of the Federal Aviation Regulations by Amendment 121-2, effective March 3, 1965[10, 11, 12]. Operators were required to conduct full-scale evacuations within a limit of 120 seconds using 50 percent of the available exits. In 1967, this established time limit was reduced to 90 seconds as amended by Section 25-46[13]. This exercise demonstrates the operator's ability to execute the established emergency evacuation procedures, and ensures realistic assignment of functions to the crew.

The requirements for the emergency evacuation demonstrations by manufacturers were established in Part 25.803 by Amendment 25-15, effective Oct. 24, 1967[14]. With seating capacity of aircraft exceeding 44 passengers, manufacturers were required to conduct full-scale evacuations within a 90 second time limit. It was considered that the manufacturer's demonstration illustrated the basic capability of a new airplane before the Part 121 requirement intended to account for crew training and adequate crew procedures developed by the individual operator. Hence, the test conditions were somewhat different. These demonstration tests provided data on (a) evacuation rates, (b) escape system performance, and (c) behavior of evacuees during the demonstrations.

It was proposed in Notice 75-26[15] that analysis, or a combination of analysis and tests, be used to show evacuation capability. By dropping the provision that allowed analysis alone and requiring a combination of analysis and tests through Amendment 25-46, this was meant to ensure approvals would be based on sufficient test data since data may not be available in the case of a completely new airplane or model that had major changes or a considerably larger passenger capacity than a previously approved model. This design stage presents an ideal opportunity for simulation.

The preamble to Amendment 121-176[16] from the FAA study of evacuation demonstrations states "that with rare exceptions, the rates of passenger egress are not significantly different for the same type of exit and that changes in the passenger cabin configuration, seat pitch, and aisle width have no significant bearing on the egress rates if the airplane type certification requirements for minimum aisle width and exit accessibility are met."

However, Muir, Bottomley, and Marrison[17] found that all increases in aperture width up to 30 inches produced significantly beneficial flow rates, but further width increase provided no additional benefits. Moreover, when comparing different aisle widths they concluded that "more bottlenecks occurred in the 24-inch configuration tests than in the 20-inch tests, even though the mean evacuation time for the former condition was less than that of the latter." This suggests that aisle widths have a possible significant bearing on egress rates even when the type certification requirements for minimum aisle width are met. Therefore, the possibility for modeling or simulating the emergency evacuation with aisle variations could prove useful in understanding human behavior and safety design.

The 1985 FAA Public Technical Conference held in Seattle, Wash., discussed the conduct of emergency evacuation demonstrations and the use of analysis in lieu of full-scale demonstrations. The rationale of such discussions was to discuss policy formulation on when to conduct evacuation demonstrations or analysis. However, no consensus could be reached concerning the analysis in lieu of full-scale demonstration's and the FAA issued AC 25.803-1 "Emergency Evacuation Demonstrations." So, the analysis used to ascertain if an evacuation needs to be conducted as well as the procedures used in conducting the evacuations are explained in the advisory circular. Ultimately, though, there is no mention to the use of alternative means of evacuation demonstrations, such as modeling or simulation, in AC 25.803-1.

Modeling or simulation of emergency evacuations could provide understanding of aircraft designs without the costs, injuries, or mock-ups required in full-scale demonstrations. Muir and Thomas' study supports this perspective when they investigated passenger safety and very large transportation aircraft. In their landmark study of passenger survival factors they concluded that, "In view of the numbers of passengers, and as a consequence the potential for injury, consideration could be given to the use of a combination of modeling and partial testing rather than a full-scale evacuation test."

Methods

Evaluation of physical factors

The first task was to assess the physical, geometrical, and temporal nature of the evacuation situation, including seat configuration and location, restraint system, distance to aisle, width of aisle, number of available exits, distance to nearest exit, headspace in front of exit, configuration and operation of the exit, as well as associated evacuation slides. An additional set of variables will be developed regarding the environmental factors in post-impact situations. Evidence regarding environment factors will be obtained from the literature and include such things as fire ignition, development and propagation, exit availability, and post-impact condition. Additional factors related to conditions of the fuselage (intact, partially intact, or fragmented) and compromises to survival such as smoke, toxic gasses, and heat have not been investigated yet. Data will be obtained from previous accidents to identify evacuation conditions, times, failure modes, and escape probabilities. Next, informed assumptions will be made regarding the numbers, characteristics and behaviors of the passengers. Finally, detailed evacuation performance requirements will be obtained from industry and FAA documents.

Simulation

The traditional methods of observing human behavior and performance, such as that in evacuation from transport aircraft, include outcome statistics (e.g., accident, fatality, injury statistics), and controlled experimentation or demonstration. The former approach has considerable validity (the events actually happened) although the exact conditions are not easily replicated and analysis (and therefore conclusions) may be flawed by missing evidence. The latter approach has good repeatability, but often questionable validity owing to the cost and potential danger to which the participants are exposed. The current method of certification of evacuation from transport aircraft is by constrained demonstration. The constraints include passenger demographic mix, exit availability, and a time limit (90 seconds). Other factors affecting behavior and performance include the aircraft configuration (seat pitch, aisle width, door dimensions, etc.) and cabin crew training, behavior, and performance. These demonstrations are usually single events and are not subject to statistical controls that address the various combinations of configuration, passenger, flight attendant, and situational variables, such as fire, smoke, aisle blockages, door and slide failures, etc.

The simulation study development includes the following levels of sophistication:

1. The basic models developed in this study included seat exit, aisle exit, door exit, and slide exit. Each of these activities was further broken down into sub activities, such as moving from one location to the next in a seat row or aisle. At this level, it is possible to simulate normal, orderly evacuation behavior, assuming fixed or variable movement times.

a. The movement time variability can assume a rectangular, exponential, lognormal, or gamma distribution.

2. The next level involves creating limited resources such as seat, aisle, door, or slide "slots," which forces queues to develop preceding the egress activity.

3. Blockages are simulated either by a probabilistic branch back into the current activity or by simply removing the availability of an exit, seat, or aisle slot resource and an activity ending effect.

a. This feature may be modeled by having a resource branching into an "occupied" state for a variable time or permanently.

4. Probabilistic branching to other pathways is introduced when a blockage (queue) develops.

a. This may involve back tracking along the aisle if an exit becomes unavailable.

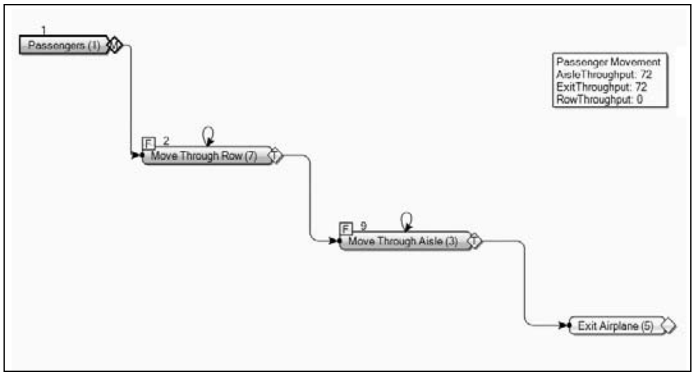

Figure 1. A basic model of evacuation processes.

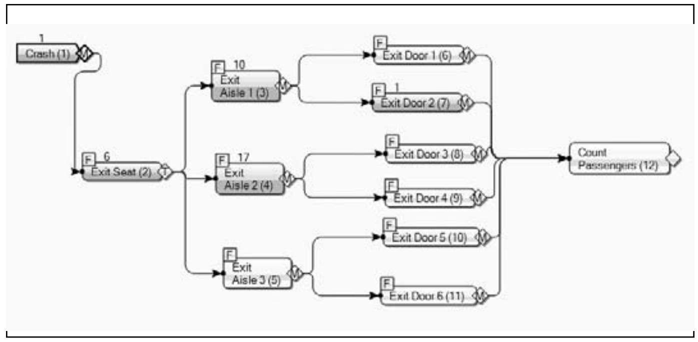

Figure 3. A model that overtly separates the different evacuation pathways.

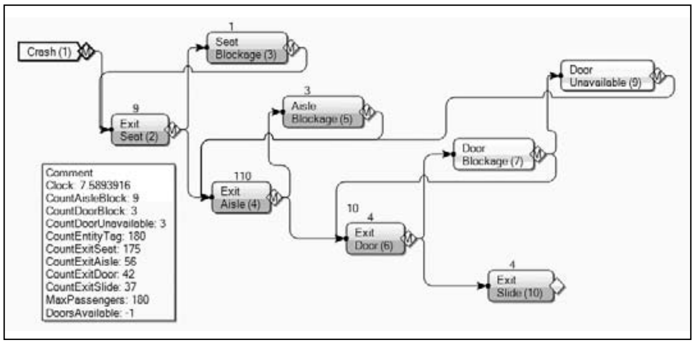

Figure 2. A model of evacuation that allows probabilistic branching to blockage conditions.

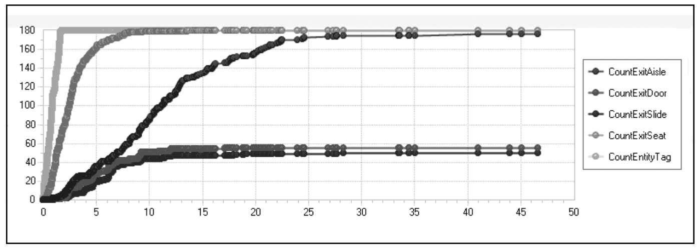

Figure 4. Typical evacuation output graphs.

5. The final level of sophistication involves the introduction of aberrant behaviors by passengers
a. There may be very large, old or handicapped passengers whose movement times are significantly slower and who may be the cause of temporary (or permanent) blockages.
b. There may be passengers who choose to take luggage with them, which can be simulated by slowing them down or by having them occupy multiple resources (e.g. aisle slots).
c. A third behavioral feature is "kin behavior" in which groups of people, such as families stick together. Again, this is simulated by linking individual entities (passengers) and having a group take up multiple spatial resources and/or move more slowly. This behavior will also increase the probability of blockages
d. The fourth group of behaviors can generally be called "panic behavior." These are characterized by irrational acts, such as freezing or pushing or going in the wrong direction and hysterical outbursts. As far as evacuation is concerned, these behaviors can be very disruptive and cause time consuming blockages.

Each of these variants is set up in Micro Saint Sharp by creating "scenarios." Furthermore, each scenario or combination of scenarios needs to be arranged according to an appropriate experimental design, and each experimental combination needs to be replicated multiple times to understand the effects of residual random variability in the implementation of the model, whose building blocks are based on classical statistical distributions.

Results to date

Three different models were developed during the first phase of this investigation as shown below in Figures 1, 2, and 3. Each of these models added a degree of sophistication to the simulation.

This basic model used exponential "service times" (Mean = 1–5 seconds per movement between "spaces") for each row, aisle, and door exit activities and updated the location of a passenger as he/she moved incrementally along a row or aisle or exited the airplane. Queues were allowed to form if a service "resource" (space) was not available.

The model in Figure 2 includes a probabilistic branch to a series (seat, aisle, and door) of blockage conditions. Furthermore, the door blockage may develop into a "door unavailable" condition, again on a probabilistic basis. Manipulation of the activity throughput times, using a Gamma distribution with means and standard deviations calculated based on the distance of the seat from the aisle and the distance of the seat row from the door. The probabilities of seat, aisle, and door blockages were systematically increased from 0.0 to 1.0.

This model explored specific exit path assignments based on seat location. Exit times were related to position in row and location of row. An extension of this model addressed looping back to alternative routes if a resource became unavailable or the waiting time for the resource exceeded an assigned amount.

Figure 4 shows the time line of movement from rows, aisles, door and slide. In this run, it can be seen that there were 180 passengers who all exited the seats after 5 seconds and the aisles after about 25 seconds. However, apparent congestion at the doors indicated that only about 50 passengers exited the doors and slides.

Discussion

The project to date has reviewed a considerable amount of the extensive literature available on this topic, and this activity is ongoing. The modeling effort to date has focused on the development of representative models, although the scarcity of actual passenger movement times in these situations is a barrier. Despite this shortcoming, and using estimated movement times and movement time variability from evacuation and industrial engineering literature, the models behave as expected. A second aspect of the modeling effort is to develop an adequate representation of blockages at various locations in the exit pathway and a discounting model of passenger behavior. This project is at the midway stage, and further refinements of the simulation will be forthcoming during the next few months. One particular value of this approach that has emerged is the ability to explore a wide range of conditions, such as movement times and "resource capacities." This demonstrated a considerable advantage over traditional live demonstrations, which are costly, dangerous, and present only a snapshot of one single set of conditions.

Conclusions

Successful emergency evacuation from large transport-category aircraft is affected by the configurations, the conditions and the capabilities and behaviors of the flight attendants and passengers. Actual demonstrations are costly, inflexible, and possibly dangerous, and furthermore do not give a reliable representation of real events. On the other hand, computer simulations, given valid models and appropriate data, are safe, inexpensive, and flexible in that many replications of different conditions can be investigated. Simulations are, therefore, valuable aids to design and performance evaluation. To date, the current project has focused on the evaluation of the many factors—configurations, regulations, training, conditions, and actual evacuations of large aircraft. Additionally, exploratory models have been developed to demonstrate the utility of the simulation approach using Microsoft Excel and Micro Saint Sharp software. It is concluded that this simulation approach is both flexible and useful. ◆

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The Accident "CAUSE" Statement—Is It Beyond Its Time?

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

***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 opinion, facts, and conclusions expressed in this paper are those of the author; the content is not a product of the U.S. National Transportation Safety Board.

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, a variety of 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, 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[1]. 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 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.[2]

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, and added 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."[3]

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.

There are many answers to that question depending upon your perspective of the process of accident and serious incident investigation. 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)[4] 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 in the mid 1970s to less than 0.1 per million departures in today's air transport fleet.[5] 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, 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 the 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 that 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' Association submission to the ICAO Accident Investigation Group Divisional meeting of 2008[6]. The Association reiterated the need to highlight the multiple issues in the accident scenario—in order to achieve the Annex 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…".[7]

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."[8]

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."[9]

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?"[10]

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."[11] 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.[12] 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.[13]

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, media representatives or successful business executives; and 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.[14] 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:

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 Vref

- 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. 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.[15] 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.[16] 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.[17] 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.[18]

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.[19] 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 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 which may never see 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. ◆

Endnotes

1. For further background information see, Historical Note on the Development of Annexes to the Convention, ICAO Annex 13, 1st ed., page 13-14.
2. In the United States, probable cause has been available to the public for more than 75 years. Records of the United States Department of Commerce, Bureau of Air Commerce indicate the first public air accident probable cause statement was published Sept. 18, 1934, CAB Report 0002, Rapid Air Lines Corporation, near Oregon, Missouri, USA. The Formal Report listed 3 causes.
3. The enabling legislation for the United States National Transportation Safety Board, the Independent Safety Board Act of 1974, as amended, requires the NTSB to establish the facts, circumstances, and cause or probable cause of air accidents-and to make a report available to the public.
4. ICAO Doc. 9859, Safety Management Manual (SSM) 2nd ed. -2009, pages 2-31.
5. Statistical Summary of Commercial Jet Airplane Accidents, Worldwide Operations, 1959-2008, the Boeing Company.
6. http://www.icao.int/AIGdiv08/docs/AIGdiv08_IP03_en.pdf.
7. ISASI Forum Volume 12, Number 3, December 1979, page 37.
8. ISASI Forum, Volume 21, Number 4, page 10. Richard Wood was the Associate Professor and Director of Aviation Safety Programs, University of Southern California.
9. ISASI Forum, Volume 22, Number 1, May 1989, page 26.
10. ISASI Forum, Volume 25, No 1, March 1992, page 9.
11. ISASI Proceedings of the 22nd International Seminar, Canberra, Australia, 1991. ISASI Forum, Volume 24, Number 4, January 1992, pages 120-135.
12. ISASI Proceedings of the 29th International Seminar, Barcelona, Spain, October, 1998, ISASI Forum, October 1998, page 26.
13. http://www.ntsb.gov/Publictn/2008/Federal-Family-Plan-Aviation-Disasters-rev-12-2008.pdf.
14. ICAO Doc. 9756, first edition 2003.
15. An example of the "factors" approach (contributing safety factors) can be seen in the Metro 23 accident report, Lockhart River Airdrome ATSB Report No. 200501977, pages 235-240. http://www.atsb.gov.au/publications/investigation_reports/2005/AAIR/aair200501977.aspx.
16. http://www.icao.int/AIGdiv08/docs/AIGdiv08_WP61_en.pdf.
17. Brazil CENIPA Report available at http://www.ntsb.gov/Aviation/Brazil-CENIPA/Midair_Collision_Final_Report_1907_English_version.pdf. See conclusions on pages 256-265. United States accredited representative comments with Findings and Probable cause are available at http://www.ntsb.gov/Aviation/Brazil-CENIPA/US_Summary_Comments.pdf.
18. http://www.tsb.gc.ca/eng/rapports-reports/aviation/2005/a05h0002/a05h0002_sec3.asp#a3.
19. ICAO State letter AN 6/1.2-09/36 dated May 28, 2009.

Accident Prevention: Pushing the Limits

By Bernard Bourdon, Accident Investigation Manager, European Aviation Safety Agency, EU

Bernard Bourdon is an engineer from France and holds a masters degree in aeronautics from the French National Civil Aviation School (ENAC[1]). He started his career in 1995 as a project manager in the French Civil Aviation Authority and joined the French Investigation Office (BEA) in 1999 as safety investigator. After 7 years managing safety investigations, he joined the European Aviation Safety Agency (EASA) in August 2006. He is currently the accident investigation manager with EASA in charge of the interface with safety investigation and the follow-up of safety recommendations. Contact Information: Bernard Bourdon, e-mail address: bernard.bourdon@easa.europa.eu, telephone number: +49 221 8999 0000.

Historical background

Europe is an old continent with centuries of anchored traditions and culture. On May 9, 1950, the French Foreign Minister Robert Schuman proposed the creation of a single authority to control the production of steel and coal in France and West Germany, to be opened for membership to other European countries. The proposal was realized in the European coal and steel community, and the plan laid the foundations for the 1957 treaties establishing the European Economic Community (EEC). Europe was born, and in 1965 the merger treaty established the European Community (EC), which set up a single council and a single commission of the European Communities, gradually eliminating the control at the internal borders of the Schengen stakeholders and establishing a common market and then a common currency. Europe has been building up synergies since then.

In the domain of air transport, the European Civil Aviation Conference[2] (ECAC) has enabled civil aviation authorities of a number of European States to cooperate in developing and implementing common safety regulatory standards and procedures. The Joint Aviation Authorities (JAA)[3] launched in 1970 is an associated body of this cooperation whose intent is to provide high and consistent standards of safety. Originally its objectives were only to produce common certification codes for large aeroplanes and for engines in order to meet the needs of European Industry and particularly for products manufactured by international consortia (e.g., Airbus). Since 1987 its work has been extended to operations, maintenance, licensing, and certification/design standards for all classes of aircraft.

The new regulatory framework: the total system approach

Within the framework of existing EU treaties and institutions, the adoption of Regulation (EC) No. 1592/2002 of the European Parliament and of the Council of July 15, 2002, established a European Aviation Safety Agency (EASA)[4] and the full performance of its functions, created a Community competence for aviation safety. The EASA has then been appointed as the executive body tasked for this objective with a view to establish and maintain a high uniform level of civil aviation safety in Europe. It has to act upon the results of air accident investigations as a matter of urgency in order to ensure consumer confidence in air transport without prejudice to Community law.

Aviation behaves as a single network involving products (aeroplanes, parts, and appliances), users (crews, operators), and supports (aerodromes, air navigation service providers). The regulatory framework must eradicate safety gaps conflicting requirements or confused responsibilities and enhance the integration of airborne and ground systems. This enhanced integration of all aviation domains in a single European regulatory framework initiated the "total system approach." Uniformity is achieved through implementing common rules adopted by the Commission. Regulations are interpreted and applied in a single way, and best practices are encouraged. Uniformity equally means protecting citizens and providing a level playing field for the internal market and in the perspective of interoperability. The "total system approach" also streamlines the certification processes and reduces the burden on regulated persons.

The EASA system is in line with "better regulation." Its possibility to combine "hard" and "soft" law provides a good answer to the needs for subsidiarity and proportionality. The Agency's approach of performance-based rulemaking implements these principles by placing essential safety elements in the rule, leaving non-essential implementation aspects to certification specifications or applicable means of compliance, which, albeit of a non-binding nature, has an important role to play in providing for a uniform implementation of common requirements with sufficient flexibility.

The gathering of executive functions is made in 3 steps:

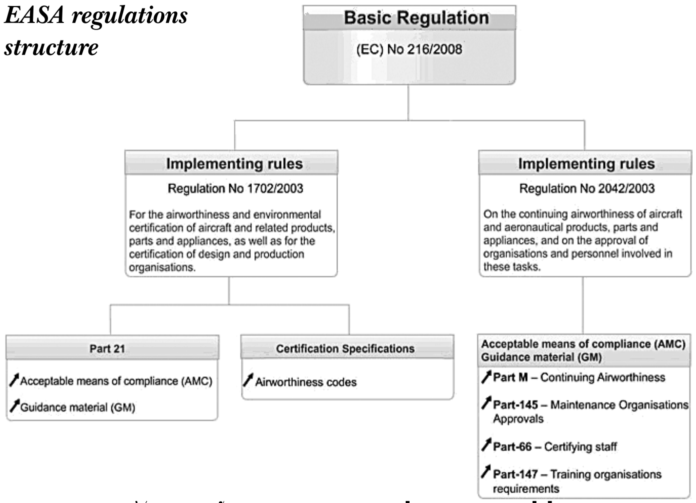
			EASA safety regulator for:	
Initial Basic Regulation	Reg. 1592/2002 of July 15, 2002	Airworthiness	The product	Total System Approach
1st extension	Reg. 216/2008 of February 20, 2008	OPS+FCL+TCO[5]	Those who use the product	
2nd extension	Reg. xxx/xxxx	ATM [6]+ Aerodrome	Those who help using the product	

Therefore, the EU aviation system is now based on shared responsibilities among members States, the European Commission, EASA, and the industry. Member States are essential pillars for implementing rules in their territory while EASA promotes community views regarding civil aviation safety standards and rules and, therefore, has taken executive powers in

- production of all EU legislation and implementation materials related to the regulation of civil aviation safety and environmental compatibility, including products certification, licensing, and operations;
- cooperation in setting international standards;
- type certification and continued airworthiness of products, parts, and appliances;

- environmental approval of products;
- approvals of organizations;
- standardization of States and the oversight of compliance with common rules; and
- oversight of non-EU operators flying to Europe.

EASA regulations structure



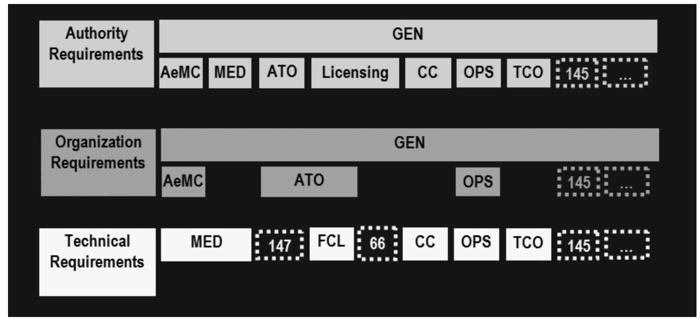
to safety risks

The historical perspective of the safety regulation shows that a reactive approach focusing on the compliance with rules prevailed. The initial focus set on technical factors in the 1950s was extended to human factors in the 1970s and, today, is expanding to organizational factors. Reactive approach to safety risk is in place for organizations. There are already requirements for quality systems, monitoring, and personnel qualification that provide compliance with rules and procedures. However, non-compliance still exists and is causing aviation accidents. It is obvious that eliminating the risk, even for an ultra safe system, is not achievable. Therefore, accident prevention requires a significant step forward in managing the safety risk by a proactive approach. The proactive approach aims at identifying hazards, managing the risk, and disseminating information in a systematic way. It backs up compliance to the rules and is based on ICAO Safety Management System[7] for organizations and state safety programs.

As a matter of fact, EASA is implementing rules proposed in the latest Notice of Proposed Amendments 2008-22 aimed at fulfilling this objective. It supports the collective oversight, aims at promoting standardization, stakeholders' management of authorities and organizations, streamlining the approval processes, and creating a high and increasing safety level though common actions.

The new regulatory scheme defines the authority requirements applicable to States and the organization requirements. The regulatory scheme aims at improving the harmonization of requirements in terms of reporting, personnel, and record keeping, while taking into account the specificity of each field. As a consequence, an air operator already approved for air transport operation would extend its activity to maintenance using its already approved general organization requirements and focusing only on the specific technical requirements for the new business. It will also avoid duplicating tasks during the oversight process. (See chart next column.)

The active role of safety investigators in a proactive approach to safety risks



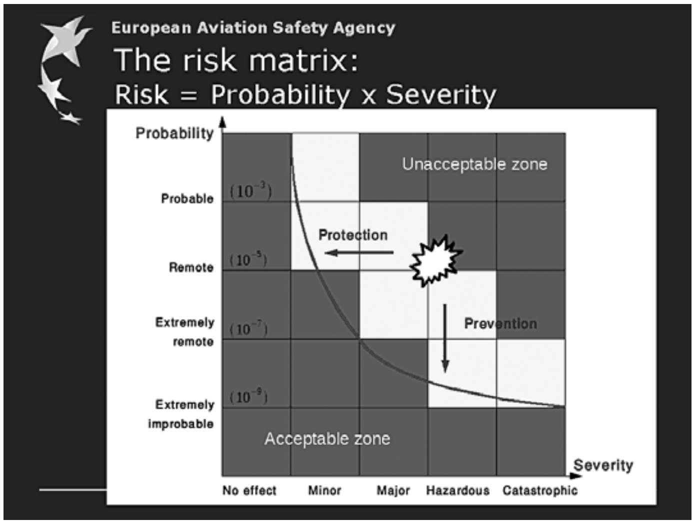
AeMC: Aeromedical Center	*66: Maintenance Certifying staff*
MED: Medical	*CC: Cabin Crew*
ATO: Air Transport Operator	*OPS: Operations*
147: Training Organization	*TCO: Third Country Operators*
FCL: Flight Crew Licensing	*145: Maintenance Organization*

The risk assessment is commonly based on a probability combined to a severity. It helps determine the likelihood of occurrences and their consequences. The risk management aims at mitigating the consequences or reducing their likelihood. Last, the risk communication enhances the knowledge of risks through better sharing of information.

to the EU safety system. It helps the following aspects of the risk assessment:

- Qualitative risk assessment based on investigation reports with a detailed description of the risks encountered. It provides an implicit and subjective approach.
- Quantitative risk assessment based on the reporting of accidents and notifications. Meaningful statistics can be drawn if the reporting is good and a significant amount of data is available. It provides an explicit and transparent approach.

Investigators provide an essential input for fixing safety deficiencies. The reporting and the dissemination of reports both are of great benefit for authorities in their decision-making process. Reporting all investigated events in a central database is as important as writing a report. The aim is to make sure that whenever a similar event is recorded, the risk assessment can be re-evaluated. Therefore, moving from a quantitative to a qualitative evaluation, the investigation work already done in the past can be reviewed in the light of the new developments.



ADREP[8] is based on a core common taxonomy for recording, exchanging, and classifying occurrences. Therefore, cross-checking similar factors using a central database is made possible with tools like Eccairs,[9] which promotes the proactive approach to safety deficiencies. ◆

Endnotes

1. www.enac.fr.
2. www.ecac-ceac.org founded in 1955 as an intergovernmental organization, the European Civil Aviation Conference seeks to harmonize civil aviation policies and practices among its Member States and, at the same time, promote understanding on policy matters between its Member States and other parts of the world.
3. www.jaa.nl. The Joint Aviation Authorities (JAA) was an associated body of the European Civil Aviation Conference (ECAC) representing the civil aviation regulatory authorities of a number of European States who had agreed to cooperate in developing and implementing common safety regulatory standards and procedures. This cooperation was intended to provide high and consistent standards of safety and a "level playing field" for competition in Europe. Much emphasis was placed on harmonizing the JAA regulations with those of the USA. The JAA Membership was based on signing the "JAA Arrangements" document originally signed by the then current Member States in Cyprus in 1990. Based on these Arrangements and related commitments, the JAA's objectives and functions may be summarized as follows:
4. www.easa.europa.eu.
5. OPS: Operations; FCL: Flight Crew Licensing; TCO: Third Country Operators.
6. ATM: Air Traffic Management
7. ICAO Doc. 9859, Safety Management Manual (SMM).
8. www.intlaviationstandards.org—"Standardizing International Taxonomies" ISASI 2007, Corey Stephens; Kyle Olsen; Olivier Ferrante; Vivek Sood.
9. http://Eccairsportal.jrc.ec.europa.eu European Coordination Center for Accident and Incident Reporting Systems *assisting national and European transport entities in collecting, sharing, and analyzing their safety information in order to improve public transport safety.*

Seminar Summary of ISASI 2009: Accident Prevention Beyond Investigation

By John Guselli, JCG Aviation Services and Chairman of ISASI's Reachout Committee

John Guselli is a director of JCG Aviation Services, an Australian company specializing in the development of transport system safety management and the delivery of specialist safety investigation training. He chairs the ISASI Reachout Committee and is co-chair of the Australian Advisory Board of the Flight Safety Foundation.

The keynote address, delivered by NTSB Chair *Deborah Hersman* set the tone for a productive seminar when she nailed the NTSB's colors to the organizational mast. Her timely declaration of transparency, accountability, and cooperation for future dealings was welcomed by all delegates. Equally well regarded were accounts of her other vital role, motherhood! We were off to a great start.

From this point, the technical program developed, commencing with *Mike Poole's* focus on the value of data in training, reinforced by *John Cox* with his somber lessons in the role of basic aerodynamics in what should have been recoverable events. The children of the magenta line present in the audience were left with no doubt as to the potential about these types of accidents.

The increasing likelihood and catastrophic consequence of runway excursions were highlighted by *Jim Burin*, who once again espoused the return on investment that could be gained from stabilized approaches. *Marcus Costa* capped this session with a timely update of the ICAO Annex 13 enhancements recently made. These were threaded through background issues related to the tragic example of the recent Air France Flight 447 accident.

The seminar took a change of heading into a preventative direction. I updated the delegates on recent ISASI Reachout initiatives and implored each person present, by example, to redress the imbalance between the safety "haves" and "have not's" in the industry. Additional preventative presentations followed.

Ryan Graue and *Geoff Edwards* detailed investigative improvements that could be achieved by using GPS data over radar data. Coupled with this, *Philippe Plantin de Hugues* brought the seminar up-to-date with current and future technology capable of functioning as lightweight flight data recorder devices.

The final session of Day 1 concluded with yet another practical example of modern technology delivering tangible benefits to aviation safety. *David Zwegers* took the seminar step by step down the path of ADS-B fitment into the Embry-Riddle national training aircraft fleet. The enhanced safety results are simple, safe, and cost effective.

Day 2 began with *Paul Arsianian*'s refreshing and realistic insight into the Air France Flight 447 investigation. His metaphor of the accident site being like "Switzerland beneath 2 miles of water" graphically established context of the difficulties under which this investigation labored. Paul incorporated significant examples from this investigation into his presentation as he touched upon key elements of societal change, scattered knowledge, and the collective amnesia afflicting many organizations. His paper concluded with a loud call for realistic policy on confidentiality in major investigations. Drawing on ICAO guidance, he implored all present to ensure that their investigative work is "based on fact and not agenda."

Seminar proceedings adjusted heading slightly to take in a raft of stimulating and relevant human factor issues. *Wen-Chin Li* provided the means compliance for large aircraft certification, while *Claudio Caceres* demonstrated the weaknesses in existing post-maintenance flight test operations. The theme continued as *Thomas Wang* discussed the benefits of the Human Factors Analysis and Classification System as well as reminding attendees of the value of checklists. Finally, *Doug Wiegmann* got with the Disney theme as he moved the seminar toward "Tomorrowland" with his work on the Human Factors Intervention Matrix (HFIX).

The comfort of the psychology domain was soon replaced by the stark reality of the world of tinkicking. *Christine Negroni* provided the seminar with chilling statistics related to the HEMS environment and at the same time proffered suggestions to take the industry to a safer place. One productive way out could well be in sharp alignment with the famous "money trail."

The seminar was further treated to the vast experience of two "old stagers" in *Ludwig Benner and Ira Rimson* as they urged all present not to forget the lessons learned from past investigations. In sharp contrast they promoted the use of technology by means of the open-source library, MESLIB. The value of this session was further enhanced by *Simon Mitchell* through his insight into best cost analysis methods for safety recommendations. The day concluded with *Gary Braman* as he advised delegates of the notion of leadership as a function of safety. In addition to his briefing the audience on the correct method of stowing fragmentation grenades, Gary cited the words of General Wickham when he called for safety practitioners to be proactive and aggressive.

The final day of the seminar opened with *Dick Newman's* excellent illustration of the pitfalls introduced to the unwary through fly-by-wire technology, particularly in the construction of MEL programs. In a similar vein, *Eric Savage* challenged all to reassess the principles that underpin emergency evacuation philosophies especially in light of passengers' ever-increasing body dimensions in comparison to the past.

Robert MacIntosh posed a most significant question—has the traditional "cause" statement passed its use-by date? His provocative words linked firmly with prior seminar statements allied to the lessons of the past.

Bernard Bourdon provided the seminar with a timely update of recent initiatives from EASA and impressed the delegation with his perspective of EASA's "total system approach in aviation safety regulation."

The concluding industry update presentations were then delivered. *Robert Sumwalt* implored us to remember why we exist as an investigative body. ISASI was challenged to produce safety recommendations that will prevent recurrence of accident and incident sequences. He amply illustrated his message through a series of structured case studies to emphasize the lessons.

David Miller then brought the assembly up-to-date with the breadth of successful work achieved by the UK AAIB. In a span from Russia to the Caribbean, and the North Sea to literally its own backyard at Heathrow, the AAIB has been stretched enormously. This led David to espouse the virtues of cooperative resources for obvious reason. He concluded with support for Paul Arsianian and highlighted the hindrances generated by the leakage of confidential information at critical stages of an investigation.

The future of ISASI was then on display as the Rudolph Kapustin Memorial Scholarship winners, *Dujuan Sevillian, Murtaza Telya,* and *Brian Dyer,* were introduced to the assembly. From their topical presentations it was obvious that they will perform valuable service to the industry into the future. Although the students were a hard act to follow, *Martine Del Bono* of the BEA, *Mark Clitsome* of the TSB, and *Ikuo Takagi* of the JTSB completed the update process for investigation throughout the world.

In closing, let me urge all delegates to measure the value of the ISASI 2009 seminar from a personal perspective and to remember that, like any structure, the strength of ISASI is dependent on the integrity of its components. ◆

GUEST SPEAKER

Communication Challenges After the Air France Flight 447 Accident

By Martine Del Bono, Head of Public Affairs Division, Bureau d'Enquêtes et d'Analyses (BEA), France

Martine Del Bono, *who graduated from the CELSA (School of Higher Studies in the Information and Communication Sciences, Sorbonne University), is the head of the public affairs division at the BEA. After diverse experience in the field of intercultural management and communication as head of the international communications at Sciences Po (Institute of Political Science) in Paris, she joined the BEA in 2002. Del Bono is involved in all aspects of the communications strategy, ranging from ensuring appropriate access to information to making people aware of crisis management, as well as promoting the interests of aviation safety.*

Good afternoon, ladies and gentlemen. Thank you for giving me this opportunity to speak to you a little bit about the interface between the technical work that you do and the world of the news media. Around 2 a.m. on June 1, 2009, Air France Flight 447 disappeared in bad weather conditions in the middle of the Atlantic. There were 216 passengers and 12 crewmembers on board.

In the hours following, no one could say where, when, or how this accident occurred.

In the days following the accident, the graphics used on the front pages of the newspapers suggested that the aircraft seemed to have been swallowed up by the Atlantic or to have disappeared into the clouds.

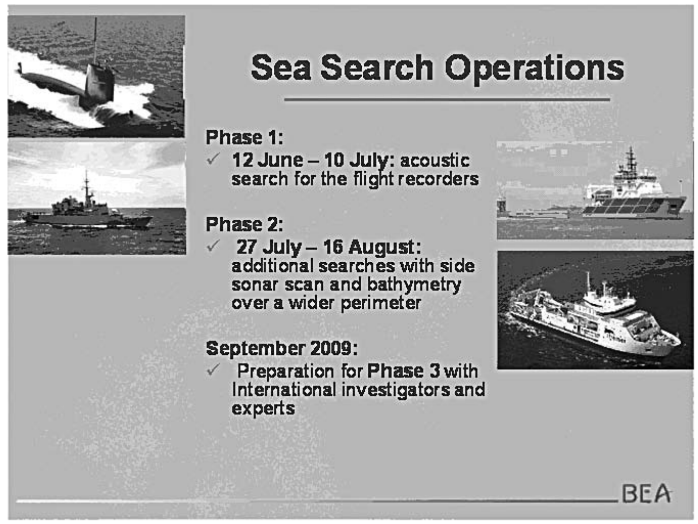
The first challenge in terms of communication with the families of the victims was the sheer number of countries that were involved even within Europe, where 21 different nationalities were touched by this tragedy. The French government appointed a former French ambassador, Pierre Jean Vandoorne, as special ambassador to handle all of the problems involving the victims' families.

This accident was described at the highest levels as an "extraordinary tragedy" as the president of the United States, Barack Obama, said to the press on June 7, 2009, during his visit in France for the ceremony in memory of the victims of World War II.

Assisted by the Brazilian, American, and French navies, the BEA coordinated the first two phases of the search operations. As you probably know, a third phase is being prepared and should begin in the coming months.

The slide on the right shows the status of the search operations as of June 18, 2009. The white circles show where we found pieces of the wreckage. In total, more than 1,000 pieces were found representing only 2 or 3% of the entire aircraft. The solid white circles show where human remains were found. In all, the remains of 50 victims have been recovered, 43 of which have been identified.

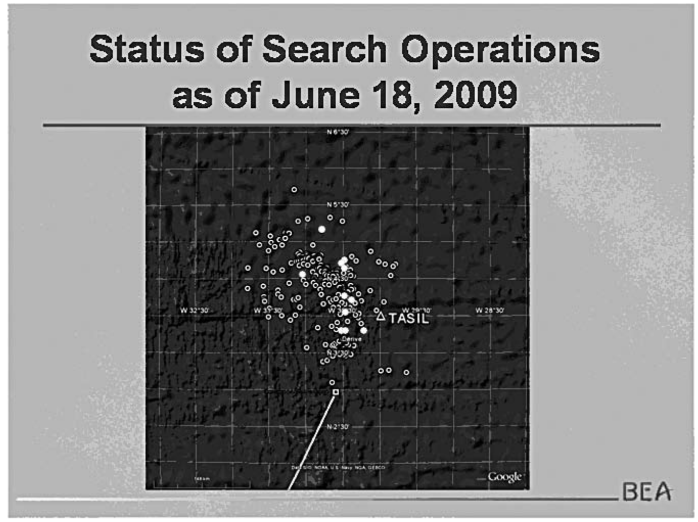
Regarding the organization of the investigation and according to Annex 13 of the Chicago Convention, France, as the state of registry, is conducting the safety investigation.



From the point of view of the news media, the participation of investigative bodies such as the CENIPA, the NTSB, the BFU, and the AAIB is a guarantee of the credibility and integrity of the French investigation,

Furthermore, as some of their citizens were among the fatalities, 12 countries requested to be named observers and to have appointed an expert. As a result, an international meeting took place at the BEA on August 5, bringing together around 40 representatives. It was the opportunity to give an update on the investigation, but also to listen to their requests, questions, and proposals.

But the BEA is also facing a multitude of other interested parties, often with conflicting interest and their own agendas with the danger that the BEA's safety message could get lost. This was our



second challenge in terms of the underlying goals of any safety investigation—particularly in the context of this accident where we had not yet found the main wreckage, where we had not yet found the flight recorders, where we did not have radar track, and where there were no eyewitnesses.

The information we had at the beginning of the investigation was 24 ACARS messages sent by the aircraft during the last 5 minutes of the flight. As you know, these messages are normally used for aircraft maintenance purposes, not for investigative purposes.

Up to 5 minutes prior to the estimated time of impact, the flight path was reconstituted and presented to the press at the BEA 2 days after the accident. Unfortunately, the ACARS messages were quickly leaked to websites and created speculation that a malfunction of the air speed sensors, also known as pitot probes, was the cause of the accident However, the BEA continued to maintain that the air speed sensors were being looked at but had not been identified as a cause of the accident.

This has been our third challenge in terms of communication: dealing with reporters who mostly did not have any knowledge of aviation or safety investigations; could not distinguish between incomplete information, findings, spin, or the causes of an accident; and could not accept the answer "we do not know," immediately interpreted as "you do not want to tell us."

During the first month, anything the BEA did or said or any comment from interested parties resulted in a news media frenzy reinforced and amplified on the Internet without regard to the affect that would have on the families. The time pressure and the news media pressure were enormous, and our top priority was to immediately update and translate into English—on our website—the information given during the press conferences.

Around 100 national and international reporters attended the presentation of the interim report on July 2 by Alan Bouillard, the BEA investigator-in-charge. The same day, within 8 hours, 30, 000 copies of the interim report were downloaded from the Internet.

Experience proves that there are peaks of news media interest following accidents, particularly after 3 months, which—in this case—corresponded to the end of the second phase of the search operations. So the news media interest was quite intense. Consequently, the public concern has remained high because of the aforementioned factors.

After more than 3 months, I would say that the biggest issue in terms of communication after a major accident is to adapt our safety message to the questions asked by reporters. By persistently explaining the safety investigator's mission and the BEA's mission we have arrived at a point where the news media message relates to the basic issues and not just to the need for a scoop.

Finally, I think it is worth underscoring the contrast between the way the news media have handled this accident and another recent major accident. I am talking about the accident involving Yemenia Flight 626, which crashed off the coast of the Comoros Islands, near Madagascar, which resulted in 152 fatalities just 1 month later. There was practically no interest from the international news media, including from the French press. The news media coverage was remarkably different even though 61 French citizens were killed on the Yemenia flight and the Comorian Investigation Commission provided regular press releases.

The only thing that interested the international news media until the recovery of the flight recorders 2 months later was the tragic story of the sole survivor, a young girl of 14.

It is as if the other 152 victims had never existed.

Thank you for listening. ◆

GUEST SPEAKER
The United Kingdom Experience

By David Miller, U.K. Deputy Chief Inspector of Air Accidents, Air Accidents Investigations Branch

***David Miller** qualified as a private pilot in 1967. He spent 17 years in the RAF becoming the officer commanding the VC 10 training unit, chief examiner for standards on the VC 10, instrument rating examiner, air-to-air refueling instructor, and VC 10 display pilot. In the civil environment, he became a training captain on Boeing 757s, 737-300s, and 737-400s. Miller joined the AIB in 1991 and in 2002 was promoted to deputy chief inspector of air accidents. He holds a current ATPL and is rated on the A300-600R, B-757, B-767, B-737, and Cessna Citation as well as Bell 47 and Bell 206 JetRanger helicopters.*

Good morning ladies and gentlemen. First let me thank the ISASI Seminar Committee for this opportunity to bring you all up-to-date on the activities concerning the United Kingdom Air Accidents Investigation Branch.

In order to do this, I feel it necessary to briefly inform those of you less familiar with the U.K. situation on the AAIB's resources, areas of responsibility, and level of activity. I will then bring the seminar up-to-date with our recent and ongoing accident investigations and issues that affect or have the potential to affect the way we all do business in the future from the U.K. perspective.

The U.K. first established an aircraft accident investigation organization in 1915 as part of the Royal Flying Corps. After World War I, it was civilianized and became known as the Accidents Investigation Branch (AIB), part of the Air Ministry. In more recent times, it was renamed the "Air" Accidents Investigation Branch (AAIB) to distinguish it from its independent sister organizations the MAIB (Marine) and RAIB (Rail). The AAIB, however, is not part of a multimodal organization like the NTSB. All three organizations remain separate, but the three chief inspectors meet regularly to discuss and share best practices.

The AAIB, part of the U.K Department for Transport, presently operates with a head count of 55. Thirty-five of these are inspectors, divided into engineering and operations specializations. The remaining 20 provide administrative support. The AAIB's operations inspectors are all current airline captains who, although full-time AAIB employees, continue to "fly the line" as captains with the leading U.K. operators. The engineering inspectors maintain their currency with the industry and their systems knowledge by attending manufacturer's and academic courses worldwide. The total running cost is approximately US$12M.

How does this establishment relate to the U.K.'s areas of responsibility and accident activity?

The AAIB is, obviously, the investigating authority when the U.K. is the state of occurrence; but what may not be widely known is that the AAIB is responsible for investigating accidents occurring in the U.K.'s crown dependencies and its overseas territories, which stretch as far afield as the Falkland Islands.

The AAIB is also responsible for appointing accredited representatives when accidents occur overseas to a U.K-registered aircraft. It is well known that the "G-" registration denotes a U.K.-registered aircraft, but it is often forgotten that the "M-," "VP-," and "VQ-" registrations are classed as subsets of the U.K. "main register" and as such fall within the AAIB's sphere of responsibility. Many of these aircraft operate permanently remote from their host register—for example, a majority of the medium-haul twin-jet transport aircraft registered in Bermuda operate permanently under 83 agreements within Russia.

With regards to the U.K. accident rates, the AAIB is notified, on average, of 790 events each year, of which 470 fall within the definition of an accident or serious incident. A significant number of these are investigated remotely through correspondence, but approximately 78 a year require the deployment of field teams. The figures for fatal accidents and the number of fatalities speak for themselves. We have no regional offices, and this work is done by the 35 investigators—that's approximately one every 6 weeks.

The figures for 2009 are for the 7-month period January to July, and already the number of fatalities is fast approaching the high figure of 44 for 2007. This figure is high due to the loss of 16 lives in one of the North Sea Super Puma helicopter accidents presently under investigation.

The AAIB continues to see general aviation fatal accidents in which pilots have either become disorientated by continuing their flight into deteriorating weather conditions without the necessary training or qualifications or have flown the aircraft such that a departure from controlled flight has occurred at an altitude in which recovery could not be completed before the aircraft hit the ground. In 2009 specifically, we have dealt with two mid-air collisions involving civil-registered but military-operated aircraft. These events tragically led to the deaths of three teenage air cadets undergoing air experience flights with the RAF. Understandably this has led to a review by the military of their training regimes.

Accidents and serious incidents to public transport aircraft, however, continue to consume the bulk of our resources, both in manpower and financial terms.

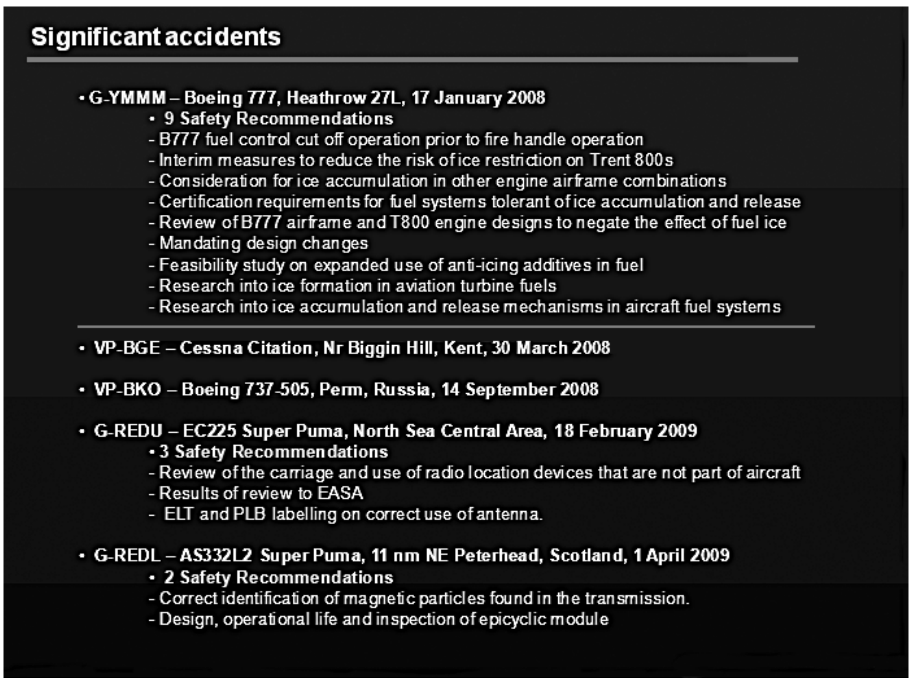
On the screen you can see here a list of some of the more significant accidents involving AAIB inspector teams. Each of these has highlighted a particular area of note. The Cessna Citation accident at Biggin Hill, in which five people died and a post-crash fire consumed a significant portion of the cockpit, fuselage, and engine accessories destroying most of the evidence, highlighted the need for the fitment of flight data and voice recorders to light turbine-powered executive aircraft.

We have already heard this week on the work carried out by the Flight Recorder Panel and that an ICAO letter to States has been issued seeking comment in this area. The AAIB would encourage endorsement of these initiatives regarding the specifications and ultimately the fitment of "robust" light-weight recorders on all commercial turbine-powered aircraft.

The investigation into the previously mentioned Cessna Citation accident also highlighted a disturbing trend in which investigators can be denied the use of valuable investigative tools such as flight simulators. The investigation team needed to examine the cockpit environment to study the man/machine interface and human factors affecting crew resource management. The inspectors, however, were denied the use of local resources and had to travel significant distances to find facilities to meet their needs.

Advances in the fidelity of flight simulators have led to them being certified for use as "zero flight time' training facilities. We all know the advantages of flight simulation, whether it is for initial training, recurrent training, testing and checking, cockpit resource management training, jet upset training, and much more. We also know their use can contribute immeasurably to an investigator's understanding of aircraft systems, aircraft performance, and crew behavior and performance.

It is sad to say, however, and this has been the AAIB experience of late, that more and more frequently investigators are being denied



the use of this investigative tool because of cooperate policy decisions brought about by the threat of potential litigation.

I admit I do not understand why or how this situation has developed, but the AAIB will continue to seek the cooperation of those that provide this type of facility. This situation causes concerns and threatens to erode a hitherto cooperative environment.

The Boeing 737 accident in Perm, Russia, served to remind the AAIB, and its overseas territories, of the need for closer monitoring of operational standards for aircraft permanently operating clear from direct oversight of the regulator.

The two North Sea Super Puma helicopter accidents that threatened to close down oil production in the North Sea, and of course the loss of the Air France A330 in the mid-Atlantic, remind all of us of the difficulties and substantial cost involved in recovering aircraft from the sea bed. In one of the North Sea accidents, the helicopter (G-REDU) had flown onto the surface and floated, allowing the occupants to escape virtually uninjured and also affording a relatively easy but still costly recovery operation.

The other helicopter (G-REDL), wherein the rotor head detached in flight killing all on board, hit the sea and sunk in four discrete sections. The weather was benign, and the subsurface visibility and sea bed were such that recovery was relatively straightforward. However, the AAIB had to set aside total costs of just under US$1.5M.

I would like to now come onto the investigation into the Boeing 777 accident at Heathrow, which is continuing, It is hoped that a final report will be published around the end of the year. Here we see a positive message.

The AAIB has already published several reports detailing the circumstances in which ice accumulating in the aircraft's fuel system was released such that it temporarily blocked the engine fuel/oil heat exchanger, preventing the engines from responding to the thrust lever demands.

The issue I would like to highlight here, however, is how cooperation among the investigators, the FAA and EASA, the operators, and the manufacturers was essential in achieving an understanding of the accident. The investigators formed only 10% of the total manpower working on this accident.

This B-777 accident raised the need for significant research using fuels system test rigs and engine power tests, as well as the analysis of monumental amounts of statistical data provided by several airlines from their FDM/QAR programs—all I might add at significant cost to the companies involved, but carried out voluntarily to achieve a common aim in support of the investigation.

I think we can sometimes become complacent in this respect and forget to acknowledge how far our industry has come in the provision of voluntary cooperation in all respects. This cooperation, however, is continually under threat and may reduce in the future.

Recent challenges in the U.K., requesting the release of confidential information, not protected under national legislation or deemed as "relevant records" under the ICAO Annex 13 definition, held by the investigation team and provided in good faith by the industry, threaten to close the door on the future free flow of information. I'm sure you will all agree that the main players must feel that their participation in any investigation is carried out in an atmosphere of mutual trust and confidentiality and safe in the knowledge that information provided, whether sought or volunteered, must be protected from uncontrolled release in the public domain

In conclusion then I would like to pose this well known question. How many accidents have been prevented as a result of safety recommendations, arising from accident investigations, made by accident investigation authorities?

I hope you will agree that we don't know, but over the decades the accident rate has reduced and the AAIB remain convinced that through cooperation and the free exchange of information, treated in confidence, that we, collectively, can continue to give the commercial aircraft traveler the confidence that his or her journey will reach a safe conclusion. Seminars like this, offering opportunities for like minded safety professionals, to meet and exchange views in the interest of global cooperation, in an informal atmosphere, continues to form part of the global safety management system. ◆

GUEST SPEAKER

Initial Investigation of Serious Accidents: The JTSB's Experience

By Ikuo Takagi, Investigator General for Aircraft Accidents, the Japan Transportation Safety Board

Ikuo Takagi is the investigator general for aircraft accidents at the Japan Transport Safety Board (JTSB), a position he has held since July 2008 when he served with the then Aircraft and Railway Accidents Investigation Commission (ARAIC) prior to the establishment of the present JTSB on Oct. 1, 2008. He joined the former Ministry of Transport in 1982 and has served in the following positions with the Civil Aviation Bureau: chief air carrier airworthiness engineer, director for noise abatement technology, director for aviation security, and safety and security inspector general. In 1982 he earned a master's degree in aeronautical engineering from Nagoya University.

Thank you, and good afternoon to everyone. It is a great pleasure to have a chance to talk at the 40th ISASI seminar today. The Japan Transportation Safety Board (JTSB) was established on Oct. 1, 2008, with the mergers of the Aircraft and Railroad Accident Investigation Commission and the Japan Marine Accident Inquiry Agency.

It is a regrettable reality that aircraft accidents may occur somewhere on the earth every day. However, a serious accident in which a large transport aircraft is involved with catastrophic damage is rare, giving ordinary accident investigators, except those from the state of aircraft design and manufacture, little chance to investigate this type of accident.

In Japan, accidents and serious incidents are combined, with somewhere between 20 and 40 cases of each year. Japan has not suffered a large aircraft accident of a scheduled airline that resulted in huge fatal injuries since one occurred in 1996 at Fukuoka International Airport in which a foreign airline was involved.

An accident of a large aircraft, operated by a domestic airline, with fatal injuries has not occurred since 1985 when JAL suffered the largest number of fatal injuries with a single aircraft (I will not discuss why Japanese airlines have not had fatal accidents for more than 20 years.). Although I have 21 investigators, only one of them has experienced investigating such catastrophic accidents. But on March 23 of this year, we were faced with a serious accident. A big aircraft operated by a foreign airline failed to land at Narita International Airport and two occupants were fatally injured. Today I'd like to present to you how we reacted to this occurrence. As we are still in the midst of investigation, I will not touch on sensitive matters such as the cause of the accident.

Initial investigation of a serious accident

FedEx Flight 80 accident—Around 6:49 a.m. on March 23, 2009, a FedEx MD-11 departing from Guangzhou International Airport in China for Narita International Airport rolled over upon landing on Runway 34L and exploded in flames. The aircraft was a cargo aircraft manned by only two occupants. Both of them suffered fatal injuries. The aircraft burned to the ground.

Notification of the accident

TV cameras are installed on the airport buildings to monitor runway activities. The accident occurred in the early morning of Monday, and it was featured repeatedly in news broadcasts using the recorded image of the doomed aircraft, which repeatedly bounced, rolled over, and exploded on the runway.

On the day of occurrence, I got up sometime before seven o'clock as usual. I turned on the TV and watched an aircraft roll over. At first I couldn't grasp what was going on. I thought a past accident image was aired for some reason, but I soon realized that was wrong and got a clear image of how the accident occurred. At the same time, this image had been seen by many of my investigators who knew of the occurrence by watching TV before being informed through the emergency call-out network. Some who were already on a commuter train found out about the accident after getting to the office.

It was around 7:20 a.m. when I received a phone call about the accident. I was preparing to immediate depart for the office.

Appointment of investigators

I arrived at the office around 8:30 a.m. Most of the investigators were already there and were busy collecting information from the airport office and police stations at Narita airport.

I decided to assign investigators from all expertise areas to be able to cope with all the aspects of the accident investigation. I assumed the IIC position. There were six investigators assigned, the most among our recent investigations.

Around 9:30 a.m. I left the office and headed for the airport by car. It was windy but warm for the season so we left the office without proper winter gear. The weather changed drastically in the afternoon with temperatures plummeting, and it began to sleet about midnight, forcing us to work in freezing temperatures.

Narita International Airport

Narita airport was opened in May 1978, and this year marks its 31st anniversary. The airport had not experienced a fatal aircraft accident before March 23 this year.

The airport serves as Japan's most important international airport with two runways, Runway A and Runway B. Runway A is 4,000 m.; however, Runway B is only 2,180 m. Because the aircraft burned and rested just beside Runway A and scattered debris and damage was on the runway, Runway A was closed. The remaining parallel Runway B became solely operational. However, long-range large aircraft were not able to takeoff or land, and flights were delayed, cancelled, or diverted to other airports, causing delays for a huge number of travelers. The demand increased to reopen Runway A as soon as possible after finishing the onsite investigation, relocating the wreckage so that it would not interfere with the operation of the runway and repairing the damage to the runway.

Documentation of the accident site

We arrived at the airport around 10:30 a.m. and hurried to the accident site after getting a rough idea of the accident. The fuselage was still smoldering, and intermittent watering by fire trucks continued. I made the first priorities to documenting and photographing scars left on the runway, debris dispersion, and wing and landing gear destruction.

My work schedule was to finish the site recording, including the fuselage, and some work that needed to be done before relocating the wreckage. The anticipated work ended in the evening, and it was already dark then. I decided to do detailed documentation after the relocation, without worrying about a time limit.

Representatives from the U.S. were supposed to join us. Because the relocation was supposed to be done before their arrival, coordination on this issue was carried out by the investigators who remained in Tokyo.

Responding to the news media

Many requests for a press conference on the accident by the IIC flooded the Public Affairs Division of the JTSB. We held two press conferences in the evening of Day 1 and Day 2. On and after Day 3, the news media interest seemed to somewhat fade. Reporters were satisfied with the end-of-the-day quick interviews, and even this type of interview was not requested on Day 6.

Relocation of the wreckage at midnight

The airport authority planned to relocate wreckage during the night in order to open Runway A the next morning. It was after 9 p.m. when all the heavy equipment necessary for relocation was assembled and the work started. In order to relocate the fuselage, it had to be severed and this necessitated our attendance to avoid valuable information from being spoiled forever by improperly severing the fuselage.

The weather deteriorated: the temperature plummeted, and it began to rain. Rain turned into sleet in the wee hours of the morning. Trembling in the cold, investigators took turns attending to the relocation.

The next morning the wreckage was relocated to an open lot, some distance away from Runway A. The damaged runway was repaired, and it was opened to operations sometime after 9 p.m. Investigators were tired from attending to the relocation all night; however, they couldn't argue with the necessity considering the importance of Narita International Airport. The wreckage was again relocated to a new place at the end of June after securing a warehouse for the storage until the investigation was completed.

The NTSB joins the investigation

The NTSB accredited representative and his advisors arrived at Narita in the evening of the 24th, one day after the occurrence and joined our daily meetings. They started the investigation on 25th. In the morning of the 25th, I briefed them on our investigation, confirmed their expertise, and we coordinated future activities.

The bilateral meeting was carried out in English; however, the level of our individual understanding differed due to our English capability. It would have taken twice the amount of time if we had used an interpreter for the meeting. In every sense, language proficiency is a high hurdle under the condition of bilateral or multilateral investigation.

Party system investigation

The NTSB uses the party system accident investigation. I had some knowledge about it. But it was my first experience to work closely with the NTSB so at first I was perplexed about its way of doing things. In Japan, it is not our usual practice to have someone who is considered or might be relevant to the cause of the accident directly joining the investigation. So I was surprised to find that the accredited rep was accompanied by about 20 advisors consisting of operators, manufactures of the aircraft and engine, pilot associations, and the like.

Although their way is different from ours, I accepted them all, considering the nature of the accident and efficiency of the investigation. I observe that our investigation has worked effectively so far.

Readout of DFDR/CVR data

Although the aircraft was equipped with an FDR and a CVR, they were not the types used by Japanese airlines. My first impression was that we could be able to retrieve data from them with our equipment. But their seeming damage caused by shock and fire made me decide to ask the NTSB to do the work. On the 26th, a non-assigned investigator flew to the U.S. with these devices. Data retrieval at the NTSB was successful.

Future investigation

During the first phase of investigation, we documented aircraft exterior damage and scars left on the runway, retrieved FDR/CVR data, and collected aircraft operations data, weather data, and the like. Our future tasks include in-depth examination of crucial aircraft components, analysis of aircraft maneuver, and the sequence of destruction at the time of the accident using data collected during the first phase. These tasks require detailed aircraft information, operator's operations manuals and the like. The cooperation of the state of design/manufacture, the U.S., is indispensable.

Lessons learned (what my investigators have learned through the initial investigation)

Not all investigative organizations around the world face serious accidents very often. I assume every country is prepared for a big accident, and Japan was. We have practiced liaison and coordination activities under simulated serious accidents with all investigators.

This accident occurred at Narita International Airport, which lies in the vicinity of Tokyo, giving us easy access to assistance from the Civil Aviation Bureau Narita office. The number of casualties was only two. If the case had been similar to the JAL 123 accident in 1985, in which an aircraft crashed into a remote steep mountain slope resulting in 520 fatal injuries, the level of difficulties would have been multiplied, and we would have had a very difficult time.

What makes accident investigation more difficult is not the size of the accident itself but peripheral factors. For instance, once the accident occurred, people from the news media and concerned individuals asked me questions, demanding opinions, decisions, etc., and all of this affects my investigation.

Emergency call network

Although it didn't work as planned, this didn't delay the investigators reaching the accident site due to the accident occurring in the early morning. Some investigators checked the occurrence at home and left their home sooner; some were already in their commuter train.

As for the number of investigators on site, at the beginning six seemed to be insufficient. This is because the investigation was carried out in an environment in which debris was scattered along the runway as long as 1,000 m. under strong wind condition that even made our walk difficult. I arranged aerial photos using a helicopter; however, I had no investigator to assign to that task and consequently got some inappropriate pictures. I guess I should have a flexible approach in terms of the numbers of the investigators involved considering the nature of the accident.

The news media

Due to poor news media preparation, it took awhile to reach an agreement with the news media on the first accident investigation press release, and we both became irritated.

News media information collection activities sometimes surpass our investigation. In this accident they utilized many fixed airport cameras and abundant man power. Moving images of the accident aircraft recorded by the fixed airport camera were aired just after the occurrence. As a result, the news media jumped to a premature, tendentious conclusion. Some of them bombarded me with questions some minutes after the commencement of my investigation: What is the cause of porpoise maneuver of the aircraft? Weren't there wind-shears at the time of the accident? This is a good example of the changed environment brought by the advanced technologies.

Usually an account of the accident aircraft is generated as a result of prudent analysis of DFDR recording, eyewitness statements, and other factors, and then it is released, if necessary, concurrently with the investigation report. In this sense the situation was completely different.

On-site investigation under limited duration

Because the accident occurred on Runway A at Narita International Airport, the onsite investigation had a limited length of time from the beginning. Detailed documentation was not possible on the spot, and all the debris were forced to be relocated. I believe my investigators did their best under the circumstance. Something has to be done to cope with this kind of situation in the future for quick and accurate investigation under time constraints.

Coordination with other investigating bodies

It is important to have good coordination with the accredited representative and advisors from the concerned states. I knew that some of my investigators do not speak English well, but I didn't take necessary measures to cope with the language problem. ISASI 2010's sub-theme is "over cultural differences and language barriers"; however, it seems that this hurdle is high and the success of investigation depends on how we cope with that. To my relief, we have enjoyed a good relationship with NTSB so far.

My future task is to mend the emergency go-system, implementing the lessons learned in this accident and to compile the accident investigation report in **ASIA** fashion—in an **A**ccurate, **S**peedy, **I**ndependent, **A**uthentic manner (like ISASI 2010's theme).

Thank you. I hope to see you all again in Sapporo next year. ◆

GUEST SPEAKER

The *Continuous* Challenge for U.S. Air Safety Investigators Assisting In International Investigations

By Dujuan B. Sevillian

Abstract

This paper addresses the significant challenges of U.S. government air safety investigators assisting with investigations within the African continent. The reader will be introduced to possible "areas of consideration" that could be used as continuous positive interfaces that the National Transportation Safety Board (NTSB) and the Federal Aviation Administration (FAA) could utilize with international investigations. Since the major role of an air safety investigator is to investigate the causes of aviation safety-related issues and provide recommendations based on findings, the reader will also be introduced to other significant roles that an air safety investigator could benefit from during and after a completed investigation. Moreover, to fulfill the international obligations of the International Civil Aviation Authority (ICAO), Annex 13 and Annex 8, the NTSB must assist as needed with international investigations.

Introduction

NTSB investigators support the standards within ICAO Annex 13 and have assisted international investigators with aircraft accidents for several years. Sending U.S.-accredited representatives to aircraft accidents builds rapport with international investigators. The various methods of exchanging technical expertise, the willingness of investigators to serve, and the continuous exchange of information to improve aviation safety around the world are just a couple ways that can improve communication within aviation safety. In 2003, the NTSB conducted a study regarding aircraft accidents around the world. According to the study, Africa and the Middle East maintained an accident rate of 1.54 fatal accidents per million flight hours and 3.62 per million flight departures. Several other agencies have conducted studies to determine why there are so many aircraft accidents in other areas of the world (NTSB, 2003). U.S. investigators have assisted the African continent with improving aviation safety. The United States Congress mandates that the NTSB promote aviation safety across the world, and it would seem pertinent that the NTSB would be an integral part in continuous aviation-safety-related improvement strategies.

On April 1, 1998, a "Safe Skies of Africa" program was initiated by the U.S. Department of Transportation (DOT) and focused on aviation safety and airline security between the U.S. and nine African nations, including Angola, Mali, Namibia, and Tanzania. According to statistics, most of the accidents in Africa are related to maintenance human factors (FAA, 2004). Since the FAA regulates the continuous analysis and surveillance of maintenance programs within the U.S., it would seem practical to assist the international aviation community of Africa within these confines. From an FAA air safety investigator perspective, and beyond just investigating accidents, areas of concentration in Africa should be the development or the continuous support with facilitating effective air carrier internal evaluation programs, aviation safety action programs, and continuous analysis and surveillance systems within Africa's air transportation system, just to name a few. These programs could assist their government and airlines to continuously improve aviation safety. These types of oversight systems and the active management of these programs have helped improve the United States air transportation system considerably over the past 10 years thus reducing the number of aircraft accidents and incidents.

Recently, the Air Transportation Oversight System (ATOS) initiative was developed by the U.S. FAA to enhance the overall system safety aspect of air carrier programs and the associated departments that require oversight by the FAA for the airline industry. As air travel increases and new aircraft are developed, there is a demand for continuous surveillance of an airline's maintenance and flight operations programs. However, this program could also help air safety investigators determine a cause(s) of an accident or incident. Since ATOS is a multifaceted system, Africa's airlines could adapt to a similar system structure. Safety culture is a key aspect with the ability for this system to produce positive and meaningful results. The airline must understand that effective organizational safety culture and the acceptance of this culture from upper-level management could make the process of investigating an incident/accident easier from the air safety investigator standpoint by helping the investigator understand the airline's dynamic culture. Seemingly enough, the utilization of the ATOS system safety attributes within Africa's airlines could be a good evaluation tool to improve air safety within Africa and possibly reduce the rate of accidents from the commercial scheduled domestic air carrier perspective.

The six ATOS system safety attributes are responsibility, authority, procedures, controls, process measurements, and interfaces. These attributes would capture areas of satisfaction and related areas of needed improvement within particular areas such as manual currency, flight operations, personnel and training, and compensatory rest requirements. Moreover, airlines would have the opportunity to utilize safety attribute inspections (SAIs) to determine if their entire processes incorporate the six safety attributes, thus meeting the requirements of Africa's Civil Aviation Agency (ACAA), and then provide an assessment to the airline utilizing elemental performance inspections (EPIs). These types of analysis and the associated results that are documented by the airlines and the ACAA could aid U.S. investigators when they proceed with assisting the applicable agency(s) with the accident or incident investigation(s). U.S. investigators would have the opportunity to share information and assist "as needed" with helping determine a cause of the incident or accident if this process is followed by utilizing the source data from the inspections. However, as stated earlier, the safety culture could be a pivotal factor in determining any primary or final cause of an incident or accident depending on the organizational safety culture make-up of the airline.

The U.S. has implemented the Commercial Aviation Safety Team (CAST), which focuses on the reduction of aircraft incidents and accidents within the U.S. The CAST team has been very successful in the reduction of aircraft accidents and incidents since its inception almost 10 years ago. The development of a similar team in Africa would seem most practical from the organizational standpoint and could aid with accident and incident investigations by providing more information regarding the aviation-safety-related incident or accident. The CAST team could be a similar infrastructure from the U.S., teaming with industry partners and other related government officials to reduce the rate of aircraft incidents and accidents in Africa. After implementing this team in Africa, there could be more of an awareness of the underlying "common threads" causing incidents and accidents within the African continent. Team investigators could meet and discuss air-safety-related incidents and accidents.

The reduction of incidents and accidents could possibly decrease the global percentage and could decrease Africa's current rate if other factors such as safety culture and organizational safety are considered. Since human-factors-related incidents and accidents continue to remain prominent within the world airline industry's flight operations programs and maintenance programs, there is a need to enhance human-factors-related programs within the airline industry. The CAST program, ATOS program, or similar types of programs could be essential to Africa's air safety enhancement and could aid air safety investigators with African-related air safety investigations; however, these types of programs will present more challenges to the air safety investigator in Africa but could reduce the amount of times the investigator is "kicking tin." ◆

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GUEST SPEAKER
Caring for the Mental Health of Air Safety Investigators

By Brian Dyer

Today's aviation industry possesses many challenges for air safety investigators. Some of these challenges include, but are not limited to, composite materials, jagged edged metals, environmental hazards, wildlife, blood-borne pathogens, parachute systems, hazmat, and aviation fluids. Among all these challenges, there is one that receives very little attention: the mental health aspects or mental preparation of air safety investigators

The International Civil Aviation Organization (ICAO) training guidelines for aircraft accident investigators (Circular 298-AN/172, page 5) recommends that investigators be trained in investigator safety, including psychological stress. The accident site safety (Section 4.1.2.5, page 8) of that same document mandates that the subject of dealing with the psychological stress of investigators and other personnel exposure to an accident site must be covered. This training does not imply that the investigators are trained to be emotionally tough. It merely prepares them for what is anticipated at an accident site.

Aircraft accident investigators (AAI) generlly arrive at the scene of an accident after the emergency services personnel. However, there are instances where the investigators are exposed to the chaotic, traumatic, and emotional situations at the scenes of accidents. While exposure to extreme psychological stressors does not always bring about negative reactions in aircraft accident investigators, there is empirical evidence that the exposure to these critical events does pose a challenge. Understanding the cases in which the investigators allow an event to become a traumatic stressor is both important and essential for diagnosis and to provide timely mitigation measures.

Recently, the awareness of the psychological impacts of traumatic and critical events has increased, and post-traumatic treatments have received considerable attention. This attention has brought greater interests in the events that are likely to lead to post-traumatic stress symptoms. Empirical evidence has found that post-traumatic stress symptoms may develop after a single exposure to a critical event. However, although clinical procedures have been developed primarily for assisting first responders, military personnel, and public safety employees (police, EMTs, firefighters) with symptoms of acute distress, there is currently no specific program developed for intervention and prevention of distress experienced by aircraft accident investigators (Coarsey-Rader, 1993).

The traumatic effects of aircraft accidents on aircraft accident investigators have received very little attention since the primitive aviation days of early aviation enthusiasts and the Wright Brothers. Aviation accidents are sometimes fatal, and aircraft accident investigators often experience graphic exposure to severe injuries, mutilated bodies, mass destruction, the stench of burnt flesh, and aviation fluids at the scenes of these accidents.

In the search for the probable causes of these accidents, the investigators are also required to conduct interviews with surviving participants, along with coworkers and the family members of the deceased crew. It is also a common practice to listen to the cockpit voice recorders (CVRs) capture the last transmissions of the pilots' conversation with air traffic control (ATC). In these final moments prior to impact, it is not uncommon to hear the vivid screams, outcries, and panic among the crewmembers as they face certain death on these doomed flights. All of these factors may contribute to the accident investigator experiencing the effects of traumatic distress and other psychological symptoms if the coping skills of that individual are overwhelmed.

It has been recognized that immediate intervention following a traumatic experience will reduce the long-term impact of acute stress and other psychological-related problems. In an attempt to mitigate the psychological effects of the traumatic exposure, formal clinical interventions have been adapted. These interventions include critical incident stress debriefing (CISD), critical incident stress management (CISM), crisis counseling (CC), and resiliency management (RM). However, despite the popularity of the many clinical applications to mitigate psychological distresses, there has been some controversy about how best to address the onset of exposure to the critical events.

Research from the International Critical Incident Stress Foundation (ICISF) demonstrated that more than 90% of individuals involved in a traumatic event would develop some type of adverse psychological effect. These psychological effects are enhanced by a number of risk factors that include, but are not limited to, previous traumatic exposure, limited intelligence or awareness, limited social support, genetics, prior mental illness, and problems associated with personal family life (Flannery, 1999).

In 1994, the American Psychiatric Association (APA) published a table of common symptoms of psychological trauma and post-traumatic stress disorder. According to the table, those who are traumatized will develop symptoms that may include intrusive recollections of the critical event, avoidance of the traumatic situation with a numbing of general responsiveness, and increased physiological arousal. An individual experiencing substantial and long-lasting cognitive, emotional, behavioral, and physical change must be treated immediately to prevent additional problems. It has been proven that early intervention can greatly reduce the time and expense of the treatment process, as each individual may have a different reaction to the traumatic distresses (Flannery, 1999). However, individuals have a tendency to feel that asking for support is a sign of weakness and results in that person ignoring the side effects, which may have irreversible effects.

It is prudent to develop a training package similar to that of OSHA's blood-borne pathogens course that may provide investigators with the mental conditioning required to address the traumatic events that are most likely to occur at accident sites. This course may include procedures to evaluate the resources within an organization and training investigating teams to develop effective communication channels for the flow of sensitive information. In addition, institutions conducting training for personnel involved in accident investigating should provide early psychological intervention, training, and/or services as a critical component of their respective programs.

In the interim, communication and educational awareness regarding exposure to critical events must continue in earnest throughout the aircraft accident investigating community. While we cannot prevent exposure to these emotional and psychological situations during the discourse of our duties, the failure to provide awareness and training may result in the investigators themselves becoming the silent victims of the disasters. ◆

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GUEST SPEAKER

Challenges to ASI Investigations

By Murtaza Telya

Aviation safety investigators (ASIs) are undervalued and berated quite often, but the fact of the matter is, ASIs are crucial and intrinsic to commercial aviation. Being an ASI can also be perilous at times; stepping into a hazardous area surrounded by debris and toxic fumes to investigate an accident can pose a serious threat, but it must be done to find the root cause of an accident and to improve aviation safety. ASIs deserve credit for improving air safety within the past decade. The average accident rate has dropped to only 1.6 per million departures between 1998 and 2007 (Boeing, 2008); however, there are still many issues that need to be addressed to improve global air safety, especially for ASIs. Some of these issues are cultural factors, detrimental news media coverage, and judicial and legal duress.

The first issue that needs to be addressed is the role of cross-cultural factors in accident investigations, particularly national cultural factors. Cultural factors are pivotal and have a significant impact on the methods of accident investigation and the interpretation of events leading to an accident. All accident investigators don't necessarily concur on the causes of an accident. For example, after the crash of Flash Airlines Flight 604 in Egypt, the NTSB and the BEA concluded that both pilots on the aircraft were insufficiently trained and attributed the accident to human error; however, Egyptian authorities persistently disagreed with the assessment and stated that the plane crashed because of a mechanical failure (Sparaco, 2006). Such biases can impede the investigation if they are not tackled properly. These differences can be attributed to the fact that Egyptians tend to be more collectivist than Westerners, which means their society is more integrated and cohesive and they don't encourage individual reprobation (Staunch, 2002). Methodologies can differ from culture to culture as well. A recent study conducted on 16 Taiwanese and 16 British ASIs found that while Taiwanese investigators focus on accidents in a holistic manner and try to understand how all the casual factors leading to an accident interact with each other, British investigators basically focus on preferred patterns of explanations and an object-oriented method of accident investigation; in other words, Eastern cultures use a holistic approach to investigate accidents while Western cultures use a more individualistic approach (Li, Young, Wang, & Harris, 2008). These cultural conflicts become quite prevalent when international accidents occur, and one must learn to utilize the differences in culture to one's advantage instead of trying to eradicate them.

Another prominent challenge that aviation investigators face is detrimental news media coverage. News media attention can be very cumbersome for investigators, since many news media outlets tend to propagate conjuncture and incomplete reports; the news media coverage of the Colgan Flight 3407 crash corroborates the aforementioned statement. News media reports propagated that the crash was caused because the plane was on autopilot in icing conditions, even though there were other factors involved, thus undermining the official investigation and misinforming the public (Learmount, 2009). Similarly, news media outlets such as *The Times* of London and *The Sun* published many inaccurate articles related to the Air France Flight 4590 crash before the investigation had concluded; they incorrectly speculated that the supposed cracking of the Concorde's wings and metal fatigue in the fan blade caused the accident (Johnson, 2003). Such misinformation can be very harmful. The news media frenzy after airline accident in certain countries is so great that investigators in Russia are compelled by the news media to finish their investigations within a year, or else they are bound to face excessive scrutiny and badgering (Bills, 2007). Finishing an investigation within a year may sound efficient; but in many cases, gathering and analyzing evidence takes a long time, and sometimes excessive pressure can compromise the quality of an investigation.

The last issue that needs to be mentioned is that of judicial and legal duress. Legal and judicial authorities tend to complicate investigations because of their unnecessary interference and unwarranted criminalization of aviation personnel involved in an accident. This needless meddling from legal authorities has become increasingly prevalent, especially since the September 11 attacks. Judges and prosecutors constantly tend to seek criminal sanctions against aviation personnel in the wake of accidents involving human error, even though the facts do not support the findings of sabotage, criminal negligence, or willful misdemeanors (Quinn, 2007). This has been illustrated in many accidents, such as Gol Airlines Flight 1907 crash, where the surviving pilots of the Embraer jet that crashed into the Gol aircraft were charged with involuntary manslaughter, even though there is no evidence (Quinn, 2007). The maintenance crew of the Concorde aircraft that crashed on July 25, 2000, experienced similar treatment from the French government, which prosecuted four Continental Airlines maintenance crewmembers for manslaughter (Quinn, 2007). Such legal pressures can have drastic ramifications for the ASI, since it discourages personnel from providing accident information that would make them susceptible to unnecessary prosecution. At times, prosecutors and judiciaries even tend to withhold valuable information from investigators; case in point, after the crash of a Cessna citation in Rome on Feb. 7, 2009, Italian authorities confiscated the cockpit and flight data records and refused to disseminate them to the ASIs, in order to conduct their criminal investigation before the accident investigation could be concluded (Flight Safety Foundation, 2009). Authorities must realize that unless there is solid evidence of sabotage or criminal negligence, crucial evidence cannot be withheld from authorities and personnel cannot be incriminated either, or else the investigation process will be hampered and safety will be compromised.

Improper accident investigation is one of the primary causes of poor safety, and even though there have been many advancements in the area of accident investigation, cultural factors, detrimental news media coverage, and unnecessary regulatory and legal duress can be cumbersome for the ASI. These issues need to be dealt with promptly and efficiently. They must be solved by improving cultural training, improving relations with news media outlets to disseminate accident information in a responsible and accurate manner, and by urging authorities to change regulations that can impede an accident investigation. These are not quick-fix solutions, but the only way to improve safety and enhance aviation is to implement them. ◆

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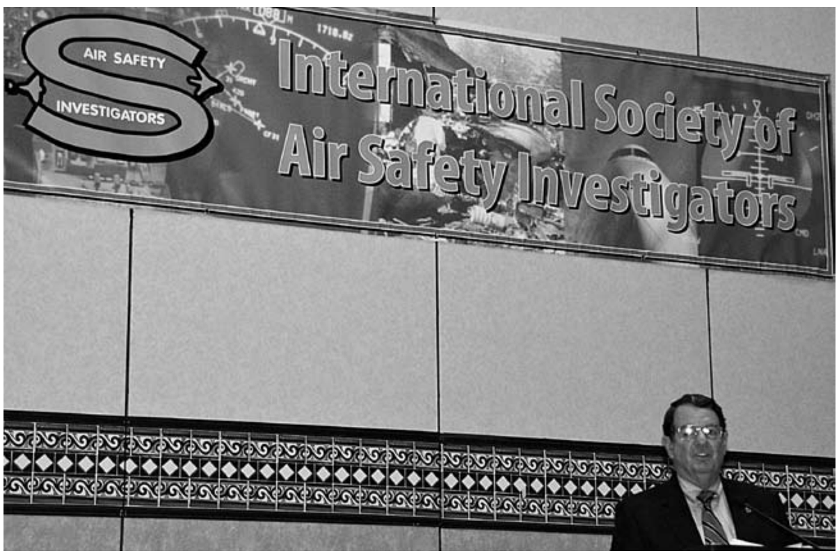


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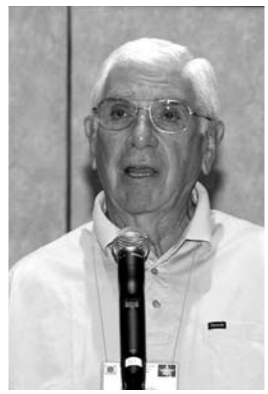
NTSB Courses
"Managing Communications During an Aircraft Disaster" (Oct. 27-28)
"Airport Preparedness Program" (Oct. 29)
One-Day Crisis Communications Course (on demand)



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