ISASI FORUM

"Air Safety Through Investigation"

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On Jan. 17, 2008, a Boeing 777-236ER powered by Rolls-Royce engines, registered G-YMMM, while on approach to London (Heathrow) experienced a loss of power to both engines, which resulted in the aircraft touching down approximately 330 meters short of the paved surface of the runway. The investigation undertaken by the United Kingdom Air Accidents Investigation Branch determined that the probable cause was the formation and sudden release of ice in the aircraft fuel delivery pipes, which caused a restriction at the engine fuel oil heat exchangers (FOHE) during a critical stage of the flight. Photo: Crown copyright by courtesy of the AAIB and Metropolitan Police ASU.

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AIR SAFETY INVESTIGATORS
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PRESIDENT'S VIEW

Revisiting ISASI's 'Criminalization' Position

By Frank Del Gandio, ISASI President

Just a year ago, I wrote on this page that your Society had become a signatory to the Joint Resolution Regarding Criminalization of Aviation Accidents. The resolution declares that criminalizing aviation accidents has a deleterious effect on the appropriate investigation of said occurrences, the finding of contributing factors and probably causation, and the formulation of recommendations to prevent recurrence.

The most recent example of such criminalization is the filing of preliminary manslaughter charges by French Judge Sylvie Zimmerman against Air France and Airbus related to the June 1, 2009, crash of Air France Flight 447. The Airbus A330 crashed into the Atlantic Ocean between Brazil and western Africa while on a flight from Rio de Janeiro to Paris. All 228 persons aboard perished. Preliminary charges allow investigating judges to continue their probe before deciding whether to send the case to trial. The BEA is now in the midst of its fourth underwater search for the flight data and voice recorders. The BEA investigation is incomplete, but problems with the pitot tube have been recognized.

I believe it is appropriate to refresh ourselves on the criminalization position we have taken along with the other signatories, including the Flight Safety Foundation, the Civil Air Navigation Services Organization (CANSO), the Royal Aeronautical Society (RAeS), the Academie Nationale de l'Air et de l'Espace (ANAE) in France, the European Regions Airline Association, the Professional Aviation Maintenance Association, and the International Federation of Air Traffic Controllers Associations, on the joint resolution.

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

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

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

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

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

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

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

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

I believe it is appropriate to refresh ourselves on the criminalization position we have taken along with the other signatories, including the Flight Safety Foundation, the Civil Air Navigation Services Organization (CANSO), the Royal Aeronautical Society (RAeS), the Academie Nationale de l'Air et de l'Espace (ANAE) in France, the European Regions Airline Association, the Professional Aviation Maintenance Association, and the International Federation of Air Traffic Controllers Associations, on the joint resolution.

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

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

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

Being convinced that criminal investigations and prosecutions in the wake of aviation accidents can interfere with the efficient and effective investigation of accidents and prevent the timely and accurate determination of probable cause and issuance of recommendations to prevent recurrence;

BE IT THEREFORE RESOLVED

that the signatory organizations

1 Declare that the paramount consideration in an aviation accident investigation should be to determine the probable cause of and contributing factors in the accident, not to punish criminally flight crews, maintenance employees, airline or manufacturer management executives, regulatory officials, or air traffic controllers. By identifying the 'what' and the 'why' of an accident, aviation safety professionals will be better equipped to address accident prevention for the future. Criminal investigations can and do hinder the critical information gathering portions of an accident investigation, and subsequently interfere with successful prevention of future aviation industry accidents.

2 Declare that, absent acts of sabotage and willful or particularly egregious reckless misconduct (including misuse of alcohol or substance abuse), criminalization of aviation accidents is not an effective deterrent or in the public interest. Professionals in the aviation industry face abundant incentives for the safe operation of flight. The aviation industry every day puts its safety reputation and human lives on the line, and has a remarkable safety record that is due in large measure to the current willingness of operators and manufacturers to cooperate fully and frankly with the investigating authorities. The benefit of gaining accurate information to increase safety standards and reduce recurring accidents greatly outweighs the retributive satisfaction of a criminal prosecution, conviction, and punishment. Increasing safety in the aviation industry is a greater benefit to society than seeking criminal punishment for those 'guilty' of human error or tragic mistakes.

3 Urge states to exercise far greater restraint and adopt stricter guidelines before officials initiate criminal investigations or bring criminal prosecutions in the wake of aviation disasters. Without any indicia of proper justification for a criminal investigation or charges, the aviation system and air disaster victims and their loved ones are better served by resort to strong regulatory oversight and rigorous

(continued on page 30)

V.P.'S CORNER

Making ISASI More Active and Dynamic

By Paul Mayes, ISASI Vice-President

The annual ISASI Executive meeting and International Council meeting (ICM) are the Society's main focus this time of year. These are the primary meetings where we can review the previous year's financial performance, the membership status, and the success of our safety seminars and workshops. And more importantly, we begin planning for the next 3-5 years and set the goals and targets for a financially sound and active Society.

We already have a very active Society with several safety programs. Everyone is aware of ISASI's annual international seminar, but there are several other seminars that attract a lot of support. Two examples are the annual Australasian Safety Seminar hosted by the Australian and New Zealand Societies and the European Safety Seminar organized by the European Society. Each year there are several other safety meetings and seminars in North America and Asia—all run and organized by volunteers. Similarly, the Reachout program continues to be a major safety program for ISASI. We are deeply indebted to our members who give their time to plan and run these events.

The working group structure is also a very positive concept for the Society, but again we rely on volunteers to give their time. Some groups are more active than others. Some have produced very valuable publications, guidelines, and "standards." Some have added to the work of ICAO and other international bodies. As a member of the Executive, I would like to encourage the working groups to be as active as possible. What can the Executive do to assist the groups and make them more active and successful?

The recent failure of the fuselage skin on a Boeing 737 in the U.S. has attracted worldwide attention, and there have been lots of news media comments and concerns for passengers. There are uninformed comments and much speculation coming from some of the news media. When an event such as this occurs, should ISASI issue a press release and have a spokesperson provide informed comments? This would be one way of bringing the Society to the attention of a much wider audience. Likewise, the recent accident of a Boeing 747 freighter due to an inflight fire, which rapidly made the aircraft uncontrollable, has serious implications for our freighter industry. Lithium batteries are again in the spotlight. Should ISASI have a position on this and produce a statement or paper to assist with introducing safety recommendations?

One of the things we will be considering at the annual International Council meeting is what else we can do to make the Society more active and to enhance our aims of promoting aviation safety worldwide.

One of the things we will be considering at the annual ICM is what else we can do to make the Society more active and to enhance our aims of promoting aviation safety worldwide. If you have any suggestions or ideas, please contact me by e-mail: candpmayes@bigpond.com. All ideas and feedback will be welcome and considered. ◆

Investigative Data Mining:
Challenges and Innovative Outcomes

The author discusses the data-mining process, results, and issues faced during the AAIB's investigation of the Boeing 777 fuel-icing accident in January 2008.

By Mark Ford, Senior Inspector of Air Accidents (Engineering), Air Accidents Investigation Branch, Department for Transport

(*This article is adapted, with permission, from the author's paper entitled* AAIB's Use of Data Mining in the Investigation of the Fuel-Icing Accident: Innovative Outcomes and Challenges Faced *presented at the ISASI 2010 seminar held in Sapporo, Japan, Sept. 6–9, 2010, which carried the theme "Investigating ASIA in Mind—Accurate, Speedy, Independent, and Authentic." The full presentation, including cited references to support the points made, can be found in* ISASI Proceedings 2010 *on the ISASI website at www.isasi.org.—Editor)*

On Jan. 17, 2008, a Boeing 777-236ER powered by Rolls-Royce engines, registered G-YMMM, while on approach to London (Heathrow) experienced a loss of power to both engines, which resulted in the aircraft touching down approximately 330 meters short of the paved surface of the runway (see Figure 1). The investigation undertaken by the United Kingdom Air Accidents Investigation Branch determined that the probable cause was the formation and sudden release of ice in the aircraft fuel delivery pipes, which caused a restriction at the engine fuel oil heat exchangers (FOHE) during a critical stage of the flight.

***Mark Ford** joined the Air Accidents Investigation Branch in 2003 and now serves as a senior inspector of air accidents, working within the Flight Data Recording and Analysis Department. Mark has worked on more than 100 hundred investigations to date and holds a private pilot's license. He formerly was with British Airways as a development engineer specializing in data acquisition and recording systems, working within the Flight Data Monitoring/Flight Operations Quality Assurance Department. Just prior to joining the AAIB, he worked as communications manager for the technical director of engineering at the airline.*

A second incident occurred on Nov. 26, 2008. A Boeing 777-200ER registration N862DA, also powered by Rolls-Royce engines, was being operated from Shanghai to Atlanta, when it suffered an uncommanded reduction in engine power during the cruise. Preliminary conclusions issued by the NTSB were that the FOHE on the right engine had become restricted with ice.

The intent of our data-mining activity was to identify if any parameters or a combination of parameters were unique to the accident flight. Also, we wanted to understand further the reason why the engine rollbacks had occurred on the G-YMMM accident flight and the later N862DA incident flight, but not on the other thousands of flights. Initial analysis of the accident flight data identified that certain fuel flow and fuel temperature features were unusual or unique when compared to a small number of flights having operated on the same route and under similar atmospheric conditions. However, it was difficult to place a statistical significance on these findings alone due to the small sample size. Analysis of a much larger data set was required, and this was best supported by tools specifically designed for the purpose of data mining. A team was formed of statisticians from QinetiQ, together with specialists from the aircraft and engine manufacturer, the operator, and the AAIB. Data points from more than half-a-million flights were analyzed during the course of the investigation.

Figure 1. G-YMMM at Runway 27L undershoot shortly after the accident.

Data mining

Data mining in itself is not a new development, but its application to aircraft accident investigation is relatively new. Humans have been "manually" extracting patterns from data for centuries, but the increasing volume of data in modern times has called for more automated approaches. Early methods of identifying patterns in data include Bayes' theorem (1700s) and regression analysis (1800s). The proliferation and increasing power of computer technology has resulted in the increased collection and storage of data. As data sets have grown in size and complexity, direct hands-on data analysis has increasingly been augmented with indirect, automatic data processing. This has been aided by other discoveries in computer science, such as neural networks, clustering, genetic algorithms (1950s), decision trees

(1960s), and support vector machines (1980s). *Data mining is the process of applying these methods to data with the intention of uncovering hidden patterns.* It has been used for many years by businesses, scientists, and governments to sift through volumes of data such as airline passenger trip records, census data, and data for market research purposes.

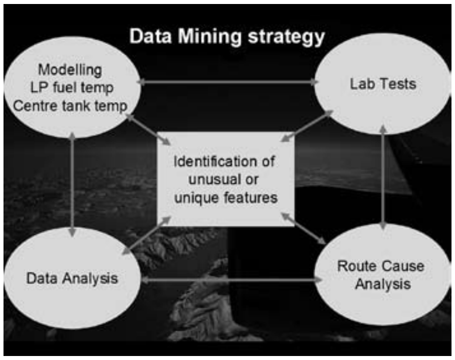
An unavoidable fact of data mining is that when analyzing subsets of data, the data may not be fully representative of the whole domain. In our case, data were not available for every flight made by Boeing 777s, so we were reliant on a smaller detailed subset equaling about 5% of the total flights (~4 million). Certain critical relationships and behaviors may only become apparent when analyzing the whole domain. The investigation team was confident that it could identify unique or unusual features from the accident flight, although the difficulty then became demonstrating if the features were contributory or causal to the accident.

Where only subsets of data have been available, data-mining results have been augmented with other approaches, such as experiments. In our case, the decision, independent of the data mining, was to conduct an exhaustive series of tests on the fuel itself and the associated fuel system to understand the principles of ice formation and its release. These tests are covered in more detail in “Heathrow 777: Investigation Challenges and Problems,” page 11, by Brian McDermid of the AAIB.

The team

The investigation benefited from having an aircraft that remained relatively intact, all the persons on board survived, there were many witnesses to the accident, and data were available from several sources. However, it was not possible to determine the most likely cause without an extensive test and research program. Early in the investigation it became apparent that the reason for the rollbacks of both engines was due to a restriction of the fuel flow, but the lack of physical evidence, apart from cavitation marks on the outlet ports of the engine high pressure fuel pumps, made the determination of the cause particularly challenging.

In the weeks immediately following the accident, data from the engine health monitoring program identified that both the takeoff fuel temperature (-2°C) and cruise fuel temperature (-34°C) were at the lower end of the distribution when compared to other flights made by Rolls-Royce-powered Boeing 777 aircraft. A second-by-second evaluation of QAR (quick access recorder) data from the operator of G-YMMM for about 50 flights also indicated that the fuel flows and temperatures were unusual in having low temperatures and flow rates during the cruise, accompanied with a series of high fuel flow rates peaking at 12,288 pph immediately before the restriction of fuel flow had occurred to both engines.



Although useful, the engine health database consisted of a series of data snapshots taken at various phases of flight, such as takeoff and while in the cruise. The trigger for the snapshots was not predicated on fuel temperature being at its minimum. While the snapshots provided a good indication of cold routes flown by the Boeing 777, it could not be guaranteed that the minimum fuel temperature had been captured. The practicable solution was to evaluate QAR data, which leant themselves to being manipulated by data-mining tools.

A data group was formed within the existing group system. The group consisted of a team of statisticians from QinetiQ (contracted to the AAIB), together with specialists from the aircraft and engine manufacturer, the operator, and the AAIB. The core team of 10 was chaired by the AAIB.

Strategy

The group’s concept was to sit within the existing investigation group structure, to identify unique or unusual features of the accident flight, and to explore the data based on requirements from other groups. It was especially important that the data group remain appraised of the fuels system testing so that analysis models could be progressively modified.

Tools for the job

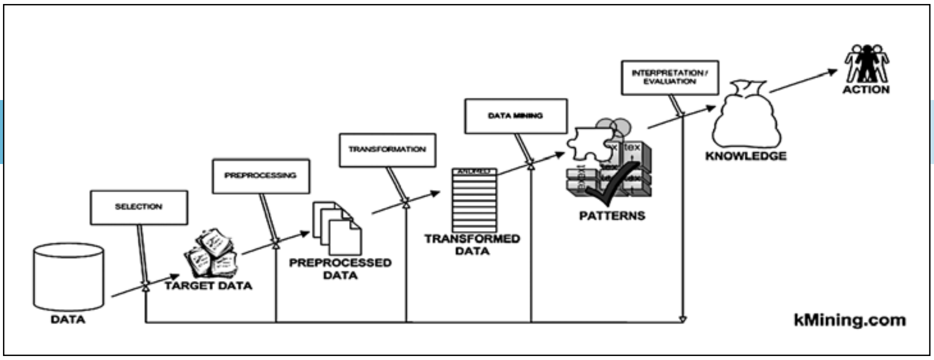
Efforts to define standards for data mining include the 1999 European Cross Industry Standard Process for Data Mining (CRISP-DM 1.0) and the 2004 Java Data Mining standard (JDM 1.0). These are evolving standards; later versions of these standards are under development. Independent of these standardization efforts, freely available open-source software systems such as the R Project, Weka, KNIME, RapidMiner, and others have become an informal standard for defining data-mining processes. Notably, all these systems are able to import and export models in PMML (Predictive Model Markup Language), which provides a standard way to represent data-mining models so that the models can be shared between different statistical applications.

Boeing and Rolls-Royce used the MATLAB application produced by Math Works with the operator using SAS. QinetiQ predominantly used SPSS although supplemented by in-house-developed applications.

The data

The data sets analyzed consisted of

- takeoff fuel temperature snapshots—**610,000** flights (11 operators globally based).
- QAR data from **13,500** flights provided by the operator of G-YMMM (~1,100 parameters).
- minimum fuel temperature snapshots from **191,000** flights (mix of northern, tropics, and southern-hemisphere-based operators).
- fuel flow and fuel temp snapshots at various phases of flight from **178,000** flights (mix of northern, tropics, and southern-



hemisphere-based operators).

The takeoff fuel temp was one of the initial data sets analyzed. The team then analyzed the QAR data before moving to obtain data from other operators.

The analysis process

The process of data mining is well documented, from the initial stages of cleaning the data to selecting analysis techniques to final processing. When applied to flight data, the process is similar to that for other data types.

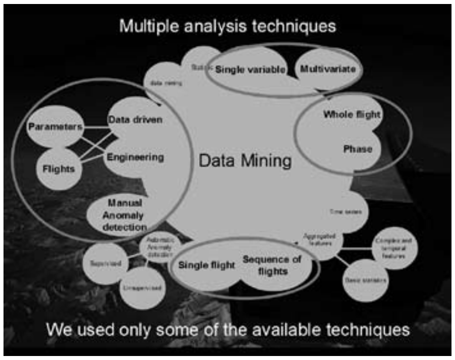
An initial 600 QAR flights were selected from the 13,500; this was termed the "training set" and consisted of the accident flight and a selection of aircraft that had operated the same route, as well as some different routes. The investigation had identified that a fuel restriction had occurred, and this enabled the team to select a sub-set of about 350 parameters from the 1,100 available. In addition to powerplant and fuel system parameters, a selection from other systems was also added; having to return to the main data set to add parameters at a later date is best avoided, if possible, due to the overhead in processing time.

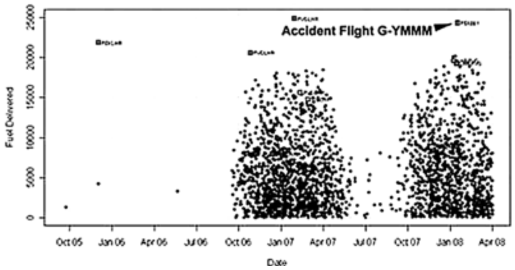
The training set was used to develop algorithms and to identify potential problems with the data, before analysis of the larger 13,500 data set. Several issues were identified with the quality of the QAR data. The most significant was that a small number of flights demonstrated sections of data where parameters changed instantaneously to a value that exceeded the practicable limits of the parameter. It was unclear if the erroneous data were a result of a defect in the QAR itself or the ACMF (Aircraft Condition Monitoring Function) system that provided data to the QAR. To ensure that these random parameter excursions did not impair the analysis, parameter filtering was rigorously tested and applied. *Failure to include cleaning techniques before mining the data may lead to erroneous results.*

While analysis of the initial 600 flights was ongoing, the operator was preparing the remaining 12,900 flights. In support of its FDM (Flight Data Monitoring program), the operator dedicated a department to the analysis of flight data. The department prepared the QAR data for the data-mining systems, extracted the selected 350 parameters, and provided it in a format agreed to with the data-mining team. Due to the quantity of data (equivalent to an excel file containing more than 400 million rows and 350 columns of data), the extraction process took more than a week, running continuously. The data were distributed on portable hard drives. Having an operator capable of pre-processing the data was beneficial. Had that capability not been available, data would need to be taken in its entirety (all 1,100 parameters) with the associated overhead of storage requirements and processing; or the data may need to be taken in its raw undecoded format and then converted to engineering units by the data-mining team.

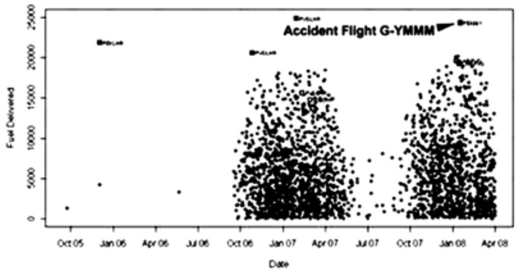
Analysis techniques and results

Data mining provided a number of analysis options, varying in degrees of complexity. Data-mining experts advised that the team should start with a simplistic approach before moving to some of the more complex techniques. This would enable us to learn about the data progressively.

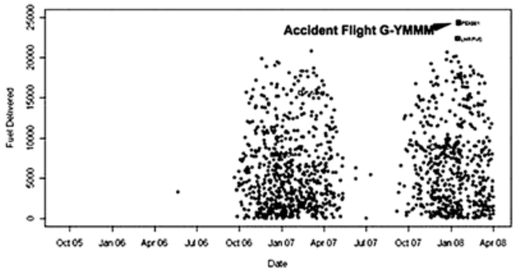




Fuel delivered at less than -20°C and max fuel flow of 10,000 pph.



Fuel delivered at less than -20°C and max fuel flow of 11,000 pph.



Fuel delivered at less than -20°C and max fuel flow of 12,000 pph.

During the investigation, the team touched on only some of the available data-mining techniques. It was difficult to automate the detection of unique or unusual features when analyzing a flight in its entirety. For example, when comparing average fuel flows of two flights, both may have been similar, but one may have uniquely experienced both a very high and low fuel flow that would not be evident in such a calculation. A number of analysis methods would need to be combined to determine if one or the other flight contained higher or lower maximum fuel flows. The highest fuel flow rates normally occur at takeoff, which again would make determination of peak fuel flows later in the flight difficult to detect. To this end, the solution was to cut each flight into sections or flight phases so each phase could be analyzed separately.

The Boeing 777, as do many other modern aircraft, calculates and records its phase of flight on the QAR. Typically, between 10 to 14 phases may be defined for modern aircraft, such as pre-start, engine start, taxi, initial takeoff roll, takeoff, initial climb, climb, top of climb, cruise, etc. The team took a more simplistic approach and cut each flight into takeoff, climb, cruise, descent, and approach phases. We found that the aircraft-generated phase was not sufficiently accurate though, with early analysis containing inaccuracies due to the data having been incorrectly cut. Later, the team developed a more robust algorithm to be run by the data-mining tools.

Once the data had been cut, it was easier to identify features of the accident flight that were unusual or perhaps unique during each flight phase. The data-mining tools could be used to extract relevant data sets, which could be readily manipulated using more simplistic spreadsheet programs. The term "outlier" was also used during the investigation, where a parameter or statistical measure was in itself not unique but sat within a small minority of flights having similar features. Some of the work based on whole flight analysis also provided some interesting results, with the accident flight being one of only a few other flights having operated for prolonged periods with fuel flows below 10,000, 11,000, and 12,000 pph with fuel temperatures below -20°C.

Although analysis tended to focus on fuel flow and fuel temperature features, each of the 350 parameters was also analyzed for unusual or unique features. Some parameters were identified as outliers, but sound engineering knowledge was able to confirm that they were not contributory or causal to the accident.

Test observations indicated that ice could form at flow rates and temperatures similar to those experienced during the accident flight. Ice could then be released at a higher flow rate, similar to that which occurred during the approach, shortly before the fuel flow had been restricted. Testing also established that water, when introduced into the fuel flow at the boost pump inlet at extremely high concentrations, could form sufficient ice to restrict fuel flow through the FOHE. During these tests it was concluded that it was not possible to restrict the fuel flow through the FOHE when the temperature of the fuel in the main tank was above -10°C and the fuel flow was less than 12,000 pph. Fuel temperature at the time of the restriction had been -22°C.

Following analysis of the initial 13,500 flights, the investigation sought to obtain additional data from other Boeing 777 operators, with the aim of establishing the uniqueness of features believed to have been contributory to the formation of ice and its subsequent release. A total of approximately 178,000 flights were obtained, a mixture of Rolls-Royce (35,000), General Electric (1,000), and Pratt and Whitney (142,000) powered aircraft. The process of how the investigation obtained this additional data is discussed later.

Initial analysis of a combination of takeoff, cruise, and approach fuel temperatures and flows identified that the accident flight was unique among the Rolls-Royce-powered aircraft flights, with 32 Pratt and Whitney powered flights having the same features:

- Fuel temperature in the main tanks below 0°C at takeoff.
- Fuel flow from the main fuel tanks less than 10,000 pph, and fuel temperature in the main tanks remaining below 0°C during the cruise.
- Fuel flow from the main tanks greater than 10,000 pph, and fuel temperature in the main tanks at or below -10°C during the approach.

Further laboratory testing confirmed that adding warm fuel to cold fuel, as would have occurred during the accident flight refueling at Beijing, or taking off with fuel below 0°C, would have had little or no bearing on whether ice was later formed on the inside of fuel feed pipes. The criterion of takeoff fuel was subsequently removed. Removal of this feature left the accident flight among a group of 66 Rolls-Royce-powered aircraft flights.

Modification of the features based on the accident flight fuel flows and fuel temperature at the time the restriction occurred, which for N862DA had also been the same at -22°C, identified that the accident flight was unique among the 35,000 Rolls-Royce-powered aircraft flights and that only two flights from 142,000 Pratt and Whitney powered aircraft flights had these same features:

- Fuel flow from the main fuel tanks less than 8,897 pph, and fuel temperature in the main tanks remaining below 0°C during the cruise.
- Fuel flow from the main tanks greater than 12,287 pph, and fuel temperature in the main tanks at or below -22°C during the approach.

Fuel temperature in flight—The accident flight's minimum fuel temperature of -34°C was identified as being unusual, although testing showed that most ice accumulates on the inside of fuel feed pipes at temperatures between -5°C and -20°C. The rate that ice accumulates will reduce as the temperature drops further toward the minimum experienced in flight. Therefore, the minimum fuel temperature experienced on the accident flight was not considered a causal factor; however, it did contribute to the low fuel temperature of -22°C on approach.

Engine fuel flow—The accident flight had operated for more than 8 hours in cruise, at an average fuel flow of about 7,000 pph. During the same period, fuel temperatures had remained below -20°C, and, due to the use of the vertical speed mode of the autopilot (which was normal) for the step climbs, fuel flows had not exceeded 8,897 pph. Testing showed that at similar temperatures and flow rates, ice can be formed within the fuel feed pipes. Testing also demonstrated that ice may be released from the fuel feed pipes at higher levels of fuel flow, similar to those attained during the final stages of the approach when the maximum fuel flow reached 12,288 pph.

Unique features—Analysis of 178,000 flights identified that the accident flight was unique among 35,000 Rolls-Royce-powered flights in having a combination of the lowest cruise fuel flow, combined with the highest fuel flow during approach while at the lowest temperature on approach. Just two flights from 142,000 Pratt and Whitney powered aircraft flights had these same features. However, analysis of the N862DA incident and subsequent data mining identified that this flight was not unique with respect to its combination of fuel temperature and fuel flows, although only a relatively small percentage (0.3%) of flights shared the same features.

Flights having similar features as the N862DA incident flight—During the incident flight of N862DA, fuel temperatures did not reduce below 0°C until about 3 hours into the flight, when the aircraft was in cruise. Fuel temperatures then progressively reduced to a minimum of -23°C. Unlike the accident flight, N862DA had made four step climbs at fuel flows in excess of 11,000 pph prior to the restriction occurring. The third and fourth step climbs both occurred at fuel temperatures below 0°C. The third occurred shortly after the fuel temperature had reduced below 0°C, and the fourth just more than 3 hours later when the fuel temperature was approaching -15°C. The fuel then continued to reduce to its minimum temperature.

About 3 hours later the aircraft carried out a further step climb, with a maximum fuel flow of just more than 11,000 pph. It was during this engine acceleration that engine oil temperature was observed to rise due to a loss of FOHE efficiency. The restriction gradually increased over a number of minutes. Fuel temperature at the time was -22°C. Approximately 20,000 Rolls-Royce-powered flights were analyzed for a combination of a maximum fuel flow of 11,000 pph and greater when in cruise and fuel temperatures of -22°C or below. Sixty flights were identified.

The search

Following the reduction in fuel flow during the accident flight, the EEC (Electronic Engine Control) system commanded maximum fuel flow to its respective engine. This command (referred to as Control Loop 17) was recorded on both the DFDR (digital flight data recorder) and QAR. The position of the FMV (fuel metering valve), which directly controls the fuel flow delivered to the engine, was also recorded, albeit only on the QAR.

Prior to the N862DA incident on Nov. 26, 2008, it had been determined that a search for previous occurrences of fuel flow restrictions be carried out. If other events could be identified, information such as similarities in fuel flow and temperatures to that of the accident flight could be established.

A retrospective analysis of the 13,500 flights provided by the operator of G-YMMM was conducted for cases of the EEC system having commanded maximum fuel flow. An algorithm was also developed to identify a mismatch between the FMV position and expected fuel flow. Other than the accident flight, no occurrences were detected. It should be noted, though, that parameter recording limitations meant that the FMV position and expected fuel flow algorithm was incapable of detecting mismatches that had resulted in less than a 2,000 pph discrepancy (the accident flight had a mismatch of more than 20,000 pph). Both detection methods were also implemented by the operator of G-YMMM as part of its ongoing fleet monitoring program. No further occurrences were detected.

For the previous 10 years, the aircraft manufacturer had records of six occurrences of the EEC system having commanded maximum fuel flow, triggering the Control Loop 17 message. Explanations were available for all of the occurrences, and they were all for reasons not relevant to the accident to G-YMMM.

Following the incident to N862DA, retrospective analysis for previous occurrences of anomalous oil pressure behavior was evaluated. Due to complexities of the engine oil pressure and FOHE relationship, an automated search of the 13,500 flights could not be readily implemented. A small subset of flights was manually analyzed, but no anomalies were found. The incident flight was also processed through the FMV position and expected fuel flow algorithm. The characteristics of the restriction to the FOHE on N862DA were different to that of G-YMMM, with a progressive rather than almost instantaneous restriction having occurred. The restriction was not detected by the algorithm until several minutes after the FOHE had started to restrict. This was due to the initial restriction resulting in less than a 2,000 pph mismatch.

Although other flights having similar levels of fuel restriction to G-YMMM and N862DA were not discovered, it could not be ruled out that other aircraft experienced a lower level of fuel flow restriction that could not be detected.

QAR and sourcing data

The release of QAR type data is an especially sensitive one for most operators. During the course of the investigation, the team had not only asked for historical data relating to the accident aircraft from the operator, but also data from across its fleet of Boeing 777s. The operator was keen to assist, but initial questions posed by the operator were, "Why do you require this much data?" and "How can it be protected?" To this end, the AAIB was able to demonstrate the need to mine the additional data, and the operator was also included within the data-mining team. The protocols for protection of the data took some time to put in place but were ensured through a combination of agreements and UK laws. The measures put in place by the AAIB ensured that the data remained protected. At the end of the investigation, the QAR data were returned.

Following analysis of the initial 13,500 flights, the investigation sought to obtain additional data from other Boeing 777 operators to determine the uniqueness of some of the features identified. A total of approximately 178,000 flights were obtained, composed of a mixture of Rolls-Royce (35,000), General Electric (1,000), and Pratt and Whitney (142,000) powered aircraft. To negate the need for operators to provide second-by-second QAR data, a specification was produced that enabled operators to extract data points using their FDM systems. The data points provided sufficient information so that the initial 13,500 flights could be compared directly with the new data. A downside of this method was that some of the FDM systems could not be readily modified. The AAIB approached all of the Rolls-Royce-powered operators and some using different manufacturers. As the team was looking at how frequent certain features could occur, the significance of different engine types was not critical during this type of analysis.

Where an engineering-based investigation is established, operators, in general, support the provision of QAR type data to accident investigators (at least in the UK). Where operational issues are being explored, the release of data is perhaps more tightly controlled. As the G-YMMM investigation was engineering based, the issue of analyzing the data for operational issues was less of a concern. It may be suggested that if the need to explore operational issues is required, the need for a data-mining program as used during the G-YMMM investigation may be negated by using the operator's own FDM/FOQA system with oversight from the investigator. Where an operator does not have an FDM system, it would be more likely that an archive of QAR data would not be available, as one of the main drivers for retaining QAR data is that of a FDM/FOQA program.

Conclusions

The investigation considered the possibility that the rollback on each engine occurred for a different reason. The fuel feed systems on each side of the aircraft are almost identical and were exposed to the same fuel, environmental factors, and motion of the aircraft. Moreover, there was a high level of repeatability during the tests to restrict the fuel flow through the FOHE and some consistency in the ice accumulation and release tests. Therefore the scenario that ice accumulated within the fuel feed system and subsequently released and restricted the fuel flow through the FOHE is consistent with the rollback on both engines occurring almost simultaneously.

The data mining was successful in its remit of identifying unusual and unique features. Through laboratory testing, it was demonstrated that fuel temperatures at the beginning of the flight were not causal to the accident but that other features were conducive to the formation and subsequent release of ice. It was not fully understood why other Rolls-Royce-powered Boeing 777 flights having similar features to the G-YMMM accident flight, and perhaps more so the N862DA incident flight, did not experience similar fuel restrictions. Laboratory testing did offer some explanation, with the observation of "randomness" in the formation of ice, indicative that there may also be a variance in the quantity of ice generated during similar flights.

Similarly, differences between the G-YMMM accident flight and N862DA incident flight, with one experiencing a more rapid onset and the other a more progressive restriction, indicate that factors other than flow rate and temperature may affect the release of ice from within fuel feed pipes. The properties of ice generated within an aircraft, rather than a laboratory environment, may also have different characteristics.

Lessons learned

- Collocation of the team. In the weeks immediately following the accident, the AAIB, Boeing, and Rolls-Royce data group staff collocated at the operator's engineering facility. This proved to be extremely beneficial for the following reasons:

—close proximity to the data ensured prompt and easy access.
—removed the difficulties of remote working, UK/U.S. time zones.
—enabled the exploration of ideas.
—number of areas expediently explored, with work being shared.
—daily debrief of progress.
—negated IT issues of inter-company data transfer.
—time to build working relationships.
—used operator software to quickly view and analyze data.

- Team selection. The team consisted of a mix of data-mining experts, subject-matter experts (fuel systems and powerplant), and flight recording specialists.

—mix of expertise proved successful, with subject-matter experts being able to steer the work of the data mining experts.

- Duplication of work

—The AAIB, Boeing, and Rolls-Royce had access to the QAR data, and each had the ability to process the data independently.
—The team had a limited resource and so had to work smartly with regard to unnecessary duplication of work.
—Did not want to constrain the exploration of the data. It was important to remain flexible and allow the exploration of data, not constrain it.
—Regular progress meetings meant that as wide an area of the data could be explored in the shortest time frame.

- IT issues

—E-mail was restrictive in transportation of flight data due to file size limitations.
—IT policies regarding usage of non-company-approved software applications.
—WebEx used for dissemination of information.
—Data transfer, portable hard drives, and encrypted data.

- Program set up—the initial planning phase proved to be time consuming.

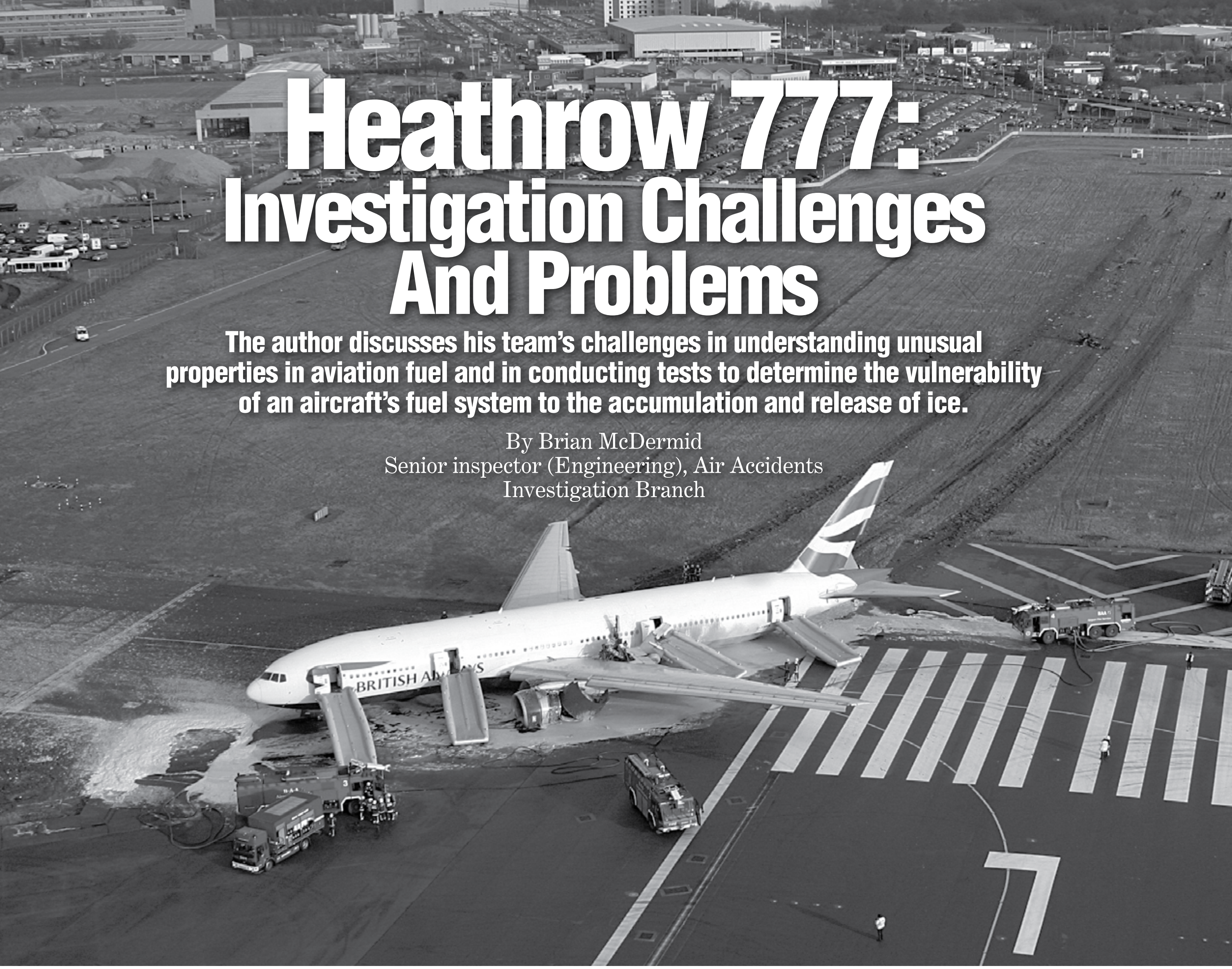
—Agreement for release of data by operator.
—Selection of data, parameters, flights, etc.
—Elapsed time to prepare the data.
—Data distribution.
—Contract of support by third parties.
—Cleaning of the data.
—Initial processing.
—Results analysis.
—Subsequent algorithms development and evolution. ◆

Heathrow 777:

Investigation Challenges And Problems

The author discusses his team's challenges in understanding unusual properties in aviation fuel and in conducting tests to determine the vulnerability of an aircraft's fuel system to the accumulation and release of ice.

By Brian McDermid
Senior inspector (Engineering), Air Accidents
Investigation Branch



(This article is adapted, with permission, from the author's paper entitled Heathrow 777: Challenges in Understanding Unusual Properties in Aviation Fuel and Problems in Conducting Tests to Determine the Vulnerability of an Aircraft's Fuel System to the Accumulation and Release of Ice *presented at the* ISASI *2010 seminar held in Sapporo, Japan, Sept. 6–9, 2010, which carried the theme "Investigating ASIA in Mind—Accurate, Speedy, Independent, and Authentic." The full presentation, including cited references to support the points made, can be found in ISASI Proceedings 2010 on the ISASI website at www.isasi.org.—Editor)*

On Jan. 17, 2008, a British Airways 777-236ER, powered by Rolls-Royce engines, registered G-YMMM, on approach to London's Heathrow Airport lost power to both engines and touched down approximately 330 meters short of the paved surface of the runway. The investigation was conducted by the UK's Air Accidents Investigation Branch (AAIB). I chaired the Fuel and Aircraft Systems Group of that investigation. In this adapted article, I will highlight some of the problems that we experienced during the investigation and give you some background on the decisions that were made and the evolution of the Boeing fuel test rig.

For my group, the initial priority was testing the fuel. And like many aspects of the investigation, the extent of the testing was agreed to by telephone conferences involving representatives from the AAIB, the NTSB, and specialists from Boeing, Rolls-Royce, and the fuels division at QinetiQ, who throughout this investigation acted as our independent fuels adviser. In excess of 66 fuel samples were taken from a variety of locations on the aircraft and engines. In addition, around three tons of fuel were removed from the aircraft fuel tanks and had to be kept in case the fuel was required for further testing. The logistics of finding a sufficient number of

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The extensive testing and examination of the aircraft fuel system could not identify a fault that would have caused the engines to roll back. Therefore, many of the fuel system components were removed and in most cases sent to the original equipment manufacturer for further inspection and testing under the supervision of one of our inspectors.

suitable containers and the secure handling of such a large number of samples were an early indication that a complex investigation of a large aircraft brings large problems, which, to an extent, dictate the pace of the investigation.

Extensive testing could identify nothing unusual about the fuel samples taken from the aircraft; and as aviation turbine fuel contains thousands of different hydrocarbons, we could not establish if there was a specific combination that made this batch of fuel more susceptible to icing. We compared the main hydrocarbon groups with the industry standards, and the fuel was found to be within the normal range. QinetiQ undertook a comparison of the fuel on the accident flight with more than 1,200 batches of fuel sampled during 2007. In terms of the distillation range, the fuel from Mike Mike was more or less in the middle of the distribution.

So that the runway could be returned to full operational use, the aircraft was moved from the accident site to a maintenance area adjacent to the threshold of Runway 27 Left. The proposed site seemed to be ideal. Close by there was a good size office, toilets, and storage facilities. Engineering support from British Airways was also readily at hand, and there was excellent IT and administrative support from our own staff. So what could possibly be wrong with such an ideal site? From the initial examination of the aircraft, analysis of the data on the flight recorders, and testing of the fuel samples, it quickly became apparent that the engine control system had functioned correctly and there was nothing apparently wrong with the fuel remaining on the aircraft. With no obvious cause for the double engine roll back, we decided to conduct a more detailed inspection and test of the aircraft fuel delivery system prior to any part of the fuel system being disturbed. This would require us to carry out pressure and vacuum tests during which we would have to listen for and trace leaks in a fuel delivery system containing more than 110 feet of fuel pipes.

Unfortunately, the hold for Runway 27 Left was adjacent to the area in which we were working on the aircraft, and it was impossible to detect any leaks over the noise from the engines of aircraft waiting to line up on the runway. The constant exposure to the noise was also very tiring; and communication, and any type of fault finding, was difficult when this runway was used for aircraft taking off. While noise-abatement procedures are a sensitive issue at Heathrow, the investigator-in-charge negotiated with the airport authorities for a 48-hour period during which Runway 27 Left would only be used for landings. However, it still took more than 24 hours for the operational changes to be instigated.

The large aircraft syndrome came into play again during inspecting and testing the aircraft fuel system. The fuel delivery pipes still contained fuel that could not be drained out. This meant that it was not possible to use the videoscopes that are normally used in the aviation industry, as they are not safe to use in an explosive environment. We tried to blow the fuel out of the pipelines with nitrogen, but this was unsuccessful, and consequently there was a further delay as we tried to find an explosive proof videoscope with a probe at least 30 feet long. A suitable videoscope was eventually hired from a company in Hamburg.

Later in the investigation, we discovered that the water industry uses explosive-proof videoscopes to inspect sewers and one was used during an inspection of another Boeing triple seven aircraft to determine where ice and water might accumulate in the fuel tanks. Nevertheless, the issue of cameras plagued us throughout this investigation, and none of the parties in the investigation could identify a suitable camera that we were happy to use in the explosive environment of a wet fuel system. Instead, we relied on still photographs taken from the videoscope.

On the positive side, we were very thankful for an early decision to accept the offer from Boeing for one of its videoscope operators to be flown over from Seattle. He was not only familiar with inspecting the inside of the fuel delivery system, but he also had a great ability to tease the probe around the many contours and corners in the long pipe runs.

The extensive testing and examination of the aircraft fuel system could not identify a fault that would have caused the engines to roll back. Therefore, many of the fuel system components were removed and in most cases sent to the original equipment manufacturer for further inspection and testing under the supervision of one of our inspectors. We also assembled the left side of the engine and aircraft fuel delivery system removed from the accident aircraft in one of our hangars at Farnborough. This reconstruction proved to be invaluable. It was the first time that most people involved in the investigation had actually seen a large aircraft fuel system laid out.

The reconstruction was also useful in identifying potential scenarios and subsequently helped us define the boundaries and factors that we wished to be included in the Boeing fuel test rig. We also constructed a fluid dynamic model of the fuel feed system, and again the reconstruction proved to be very useful as pipe dimensions and gradients could be taken directly from the reconstruction.

While the work on the aircraft was still ongoing, representatives from all the parties in the investigation met in Seattle to develop possible scenarios and provide technical support for the fieldwork. As various causes were eliminated, the possibility that ice in the fuel might have caused the accident gradually took greater precedence, and Boeing identified two of its test facilities where it could carryout some fuel system icing tests.

Small-scale tests

Small-scale fuel testing was done in a climatic chamber at the Boeing Kent facility to allow us to understand how ice forms in cold fuel. At the same time, Boeing assembled a large-scale fuel test rig at its north Boeing field facility. While it was not intended to replicate the fuel system on the aircraft, the rig did use 2-inch diameter fuel pipes and components fitted to the Boeing triple seven aircraft and the Trent 800 engine. Over time a number of changes were made to the rig such that it became more complex, and components such as the engine-driven low pressure fuel pump was fitted and hot oil was fed to the fuel oil heat exchanger.

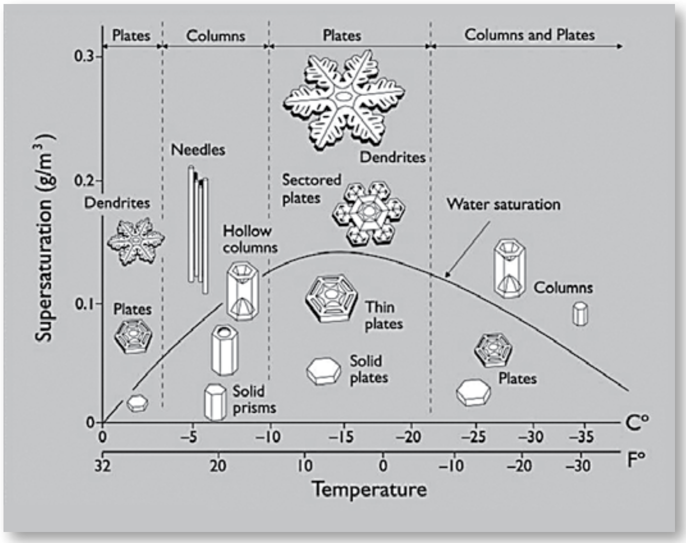


Figure 1: The crystal structure of water ice at different temperatures.

The tests carried out on the rig consistently proved that it was possible to restrict the fuel flow through a hot fuel oil heat exchanger with a relatively small quantity of water, providing the water was introduced at a high enough concentration.

However, we had less success in generating ice in other parts of the fuel system; and even with identical conditions, we experienced poor repeatability and the term "the randomness of ice" regularly cropped up in test reports and briefings. Consequently, we began to question if the variations between the aircraft and fuel test rig, and the technical innovations used to try and maintain the water concentration in cold fuel, might mask other subtle causal factors with the risk that we might inadvertently engineer a restriction that could not occur in flight.

It is worth stating that there was tremendous support from within the aviation industry. While Boeing was running the tests on its fuel rig, we explored the problems of ice forming in aircraft fuel systems with other aircraft manufacturers, universities, and research organizations. Information was also freely exchanged between Airbus and Boeing, which both use the Trent engine on their aircraft. As investigators, we go to great lengths to protect proprietary information, and therefore it was a new experience to be in the same room with two of the major aircraft manufacturers as they described how their fuel systems were designed and discussed how the system may or may not be susceptible to icing. We were also present at a similar meeting that Boeing arranged with Rolls-Royce, GE, and Pratt and Whitney.

Fuel icing

Documentation searches showed that fuel icing was a known problem on civil aircraft in the 1940s and 1950s and that some research had been carried out to address problems such as blocked inlet screens and fuel filters. While these early papers frequently recommended that further research was required to understand the root cause of fuel icing, the recommendations did not appear to have been taken forward. Instead, measures such as fuel heaters and filter bypasses were introduced, which addressed the symptom rather than the root cause.

During the 1950s, the United States Air Force suspected that a number of accidents involving B-52 aircraft were caused by ice in the fuel system; but given the perishable nature of ice, it could not find any evidence. That was until 1958 when on a cold day, all eight engines on a B-52 lost power during the approach, and the aircraft crashed in South Dakota where the ambient temperature was below freezing. Despite the aircraft catching fire, ice was found throughout the fuel system and in the engine fuel filters.

Because of this finding, the United States Air Force initiated an extensive research program that resulted in the development and introduction of a fuel system icing inhibitor. However, it is extremely difficult to establish what research military organizations have carried out. It is even more difficult to obtain copies of their test reports. This is a particular problem with foreign military organizations. But we also had difficulty in obtaining test reports for the spar valve fitted to the Boeing triple seven as the testing had been carried out to meet a military requirement. Despite this difficulty, some test reports and supporting documentation were eventually released to the investigation.

Figure 1 shows the crystal structure of water ice at different temperatures, and I think most of you can look at some of these structures and hazard a guess at the properties of the ice. Would you be surprised if I told you that this was taken from a snow boarding website on the Internet, and no one in the aviation, or fuel industry, could provide us with anything like this for ice that forms in aviation fuel?

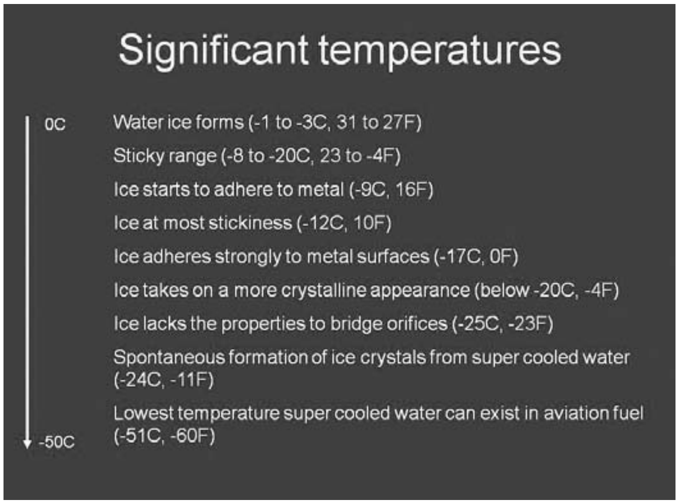
The more we delved into the early research papers on fuel system icing, the more we began to understand how complex it is. The size, and perhaps the type, of the ice crystals is dependent on the size of the water droplets, the rate of cooling, amount of agitation, and the number and type of nuclei. Large water droplets settle quickly; larger ice crystals cannot negotiate corners as easily as smaller crystals. As an industry, we appear to know relatively little about ice in fuel. This lack of knowledge was a concern to us during the investigation as we could not be totally sure that the type of ice that we generated on the fuel test rig was representative of the ice that is generated in flight.

The data-mining group activity identified the low temperatures experienced on the accident flight as being a possible significant factor, and there were suggestions from certain quarters outside the Air Accident Investigation Branch that as an interim measure the Boeing triple seven should not be used on routes where extreme low temperatures were likely to be encountered. However, from our documentation review we knew that it was difficult for ice to adhere to components when the fuel temperature was extremely low and that ice was most likely to accumulate when the fuel temperature was between -8 and -20 degrees Celsius.

Figure 2 summarizes some of the facts we know about water ice in aviation fuel, though I should caveat this information by warning you that these temperature bands are not well defined and that several papers appear to contradict each other. While we had some knowledge of the sticky range of ice, we could not say with any great confidence that the very low fuel temperature experienced on the accident flight was a coincidence, rather than a causal factor, until we analyzed the data from the roll back that occurred on one of the engines on a Delta aircraft in November 2008.

Flight testing

With our increasing concern that the Boeing fuel test rig might mask some subtle factor, a number of options were explored to try to more accurately replicate the aircraft installation and the environment during



Significant temperatures

0C

Water ice forms (-1 to -3C, 31 to 27F)

Sticky range (-8 to -20C, 23 to -4F)

Ice starts to adhere to metal (-9C, 16F)

Ice at most stickiness (-12C, 10F)

Ice adheres strongly to metal surfaces (-17C, 0F)

Ice takes on a more crystalline appearance (below -20C, -4F)

Ice lacks the properties to bridge orifices (-25C, -23F)

Spontaneous formation of ice crystals from super cooled water (-24C, -11F)

Lowest temperature super cooled water can exist in aviation fuel (-51C, -60F)

-50C

Figure 2: A summary of some of the facts we know about water ice in aviation fuel.

> **It is important that the regulative authorities instigate a number of coherent research programs into fuel system icing in order to underpin the future design and certification requirements for commercial aircraft.**

the accident flight. These options included flight testing, full scale testing of an aircraft in a climatic chamber, and testing the fuel system in an environmental test rig.

Flight testing initially appeared to be the most obvious choice and was something that Boeing and Rolls-Royce were prepared to support. The main advantage is that you test the actual aircraft systems in its normal operating environment. However, a number of disadvantages swayed us from going down this path:

- We needed a suitable aircraft that might need to be modified with sensors and recorders.
- We would have been unable to control the external environment.
- We weren't sure what we were looking for.
- Since a fuel flow restriction caused by a blockage of ice was such a rare event, there was a real possibility that it might not occur during any of the test flights.

There was also the difficulty in establishing when ice was forming as the roll back experienced on the accident flight would require around 97% of the cross-sectional area of the pipe to be blocked by ice. A lesser amount of ice would have little effect on the fuel pressure and temperature, so pressure and temperature instrumentation would have been of little help. We also could not use cameras to detect the accumulation of ice as cold fuel containing suspended water, and ice, is very cloudy.

The McKinley climatic chamber at Eglin Air Force Base in Florida was identified as a suitable facility in which to conduct full scale testing of a Boeing triple seven aircraft. The downside was that the facility is heavily used and there was only a 3-week window available, which would have given us around 10 days of testing. The facility would have allowed us to expose the aircraft to the total air temperature experienced during the accident flight for an unlimited period. We could have used the aircraft boost pumps to pump fuel from the main tanks to the engine where the fuel would be tapped off to a collector tank. Alternatively, we could have run one of the engines at cruise power for one hour at the fuel flow experienced during the accident flight. Unfortunately, like the flight testing option, we would still have the problems of aircraft availability, matching all the environmental factors, and the detection of the formation of ice.

Single pass testing

Testing the fuel system in an environmental fuel rig appeared to be the only viable option remaining, and we discussed our desired requirement for a single pass test of sections of the aircraft fuel system with a number of agencies. Single pass testing is where fresh conditioned fuel is pumped from a supply tank through the test section and into a collector tank. For a large aircraft system, this requires a considerable quantity of fresh fuel that needs to be stored and cooled down to the required temperature.

By recirculating the fuel, it is possible to use a smaller quantity of fuel and therefore smaller storage tanks. However, a disadvantage of a recirculating test rig is that it effectively dries the fuel out, and we were concerned that introducing additional water to maintain the required concentration might give us unrepresentative results. Unfortunately, few facilities could carry out single pass testing on the scale required.

In the end we had to accept the limitations of a recirculating test rig in order to achieve the desired long endurance runs, which were necessary to establish if ice would accumulate along the inside of the fuel delivery pipes. We were fortunate that Boeing had a suitable fuel tank available in which we could mount the fuel delivery pipes removed from the right main fuel tank of Mike Mike. These fuel pipes were fed from a supply tank that had been cooled and conditioned with water to represent the condition of the fuel during the accident flight.

The results from the environmental testing were very consistent, and the final test proved the theory that ice can build up in the pipes and then release in a sufficient quantity to restrict the fuel flow through the fuel oil heat exchanger.

This has been a very quick overview of the fuel systems aspect of the Mike Mike investigation. However, I hope that you do not fall into the trap of believing that it was a fault in either the fuel oil heat exchanger or the aircraft fuel system that was the cause of the accident to the British Airways Boeing triple seven. Modification of the FOHE will make the system more tolerant of ice, but it will not prevent ice accretion and release within the fuel feed system.

The problem of fuel system icing was identified in the 1940s and 1950s and recommendations were made on a number of occasions that further research was required to fully understand the extent of the problem. However, research to establish the root cause of fuel system icing does not appear to have been carried out, and instead a number of measures such as the introduction of fuel heaters and bypasses were introduced to fix specific problems.

But as we have seen, these measures only store up problems for the future, and we do not know what combination of aircraft, engine, and environmental factors will result in the next fuel icing accident. It is for this reason that the we believe it is important that the regulative authorities instigate a number of coherent research programs into fuel system icing in order to underpin the future design and certification requirements for commercial aircraft. ◆

A NEW TERRAIN PROFILE ANALYSIS TECHNIQUE

By using the radio altimeter and the pressure altitude parameters recorded in the FDR, it's possible to determine the terrain's topographic profile, which when compared to the terrain's actual profile obtained from the SRTM (Shuttle Radar Topography Mission) data allows for refinement or validation of a rough trajectory obtained from less-accurate means.

By Frederico Moreira Machado and Umberto Irgang, Embraer Air Safety Department

(This article is adapted, with permission, from the authors' paper entitled Terrain Profile Analysis using Radio Altimeter Data from FDR *presented at the* ISASI *2010 seminar held in Sapporo, Japan, Sept. 6–9, 2010, which carried the theme "Investigating ASIA in Mind—Accurate, Speedy, Independent, and Authentic." The full presentation, including cited references to support the points made, can be found in* ISASI Proceedings 2010 *on the ISASI website at www.isasi.org.—Editor)*

From 1999 through 2008, according to Boeing's statistical summary of commercial jets, 56 percent of fatal accidents occurred during either takeoff, initial climb, final approach, or landing phases. This statistic indicates that every organization in the industry somehow involved with accident investigation must be prepared to investigate that class of accident. Fortunately and of late, more parameters are being recorded in flight data recorders (FDRs). This allows for a more detailed analysis, thus improving the investigator's work of determining the contributing factors of the occurrences.

However, thousands of older generation aircraft are still in operational today. These aircraft represent a challenge to flight data analysts as a restrictive set of parameters is recorded in the FDR, making it more difficult to draw conclusions from the limited information available.

Furthermore, even new generation aircraft fitted with solid-state recorders are subject to the shortage of important parameters due to external factors. An example of this is the lack of ILS deviation parameters on approach and landing accidents that occur on airports that are not equipped with an ILS system.

The basis of this article is the involve-

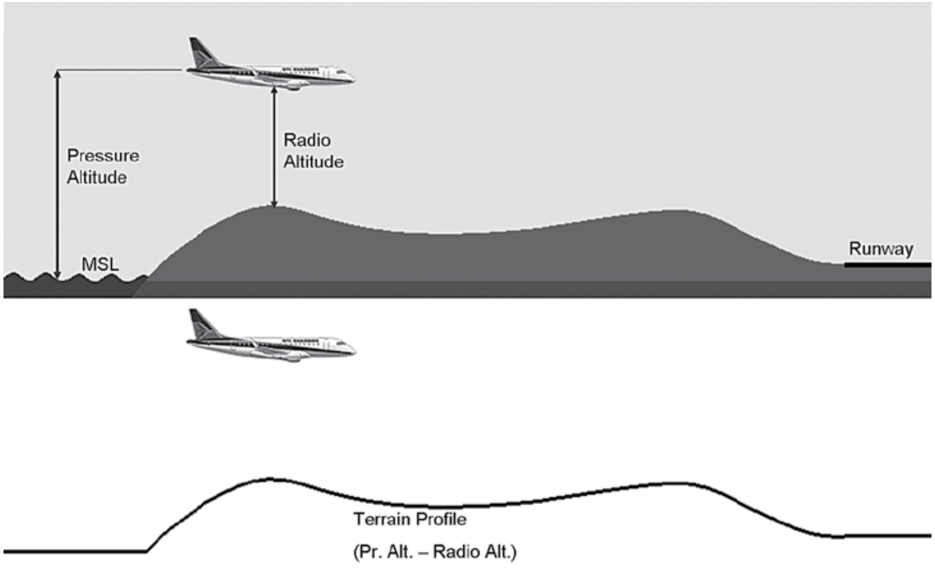
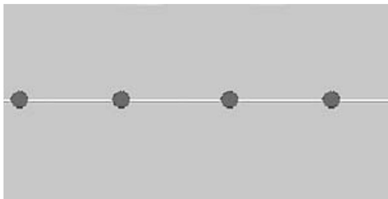


Figure 1. Determination of the terrain profile by subtracting the value of the radio altitude parameter from the pressure altitude parameter.



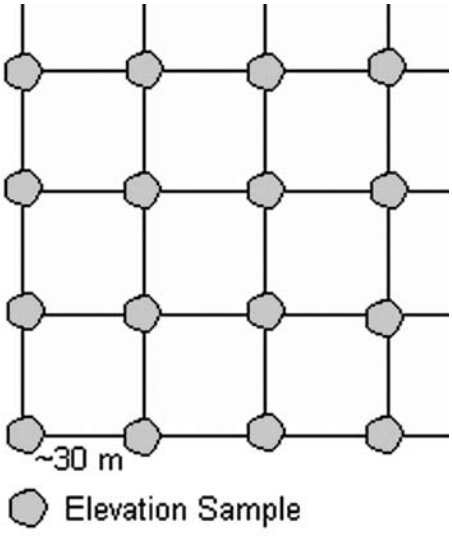


Figure 2. Schematic representation of a 1 arc-sec resolution SRTM tile.

ment of an Embraer-manufactured aircraft in a runway excursion accident at an airport that lacked this system and for which Embraer provided support to the investigation authority. The lack of geographic coordinates and ILS parameters in the FDR motivated Embraer to develop a technique that relies on altitude parameters to draw the terrain contour of the region over which the aircraft has flown. By comparing the terrain profile obtained from the FDR parameters with the actual terrain contour obtained by topographic data, it was possible to "link" the aircraft trajectory with the ground, i.e., determine the touchdown point on the runway. Several other studies have addressed the subject of trajectory reconstruction; but in this case, the parties involved were not able to determine the aircraft position with respect to the ground with the parameters available. As in any other flight data analysis technique, this technique must be applied when accident circumstances are suitable for it. And the results should be cross-checked with every other source of information available so that wrong conclusions aren't reached.

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Umberto Irgang *holds a Bsc in mechanical engineering, and an Msc level in aviation propulsion. He is the air safety senior manager at the Embraer headquarters in Sao Jose dos Campos, Brazil. He is responsible for the corporate activities of the Air Safety Department and the air safety offices in the North American, Europe/Africa, Asia Pacific, and China regions, with his main activities encompassing data analysis, occurrences investigation, safety prevention, and product safety monitoring.*

To explain this new technique, we need to begin with a description of the determination of the terrain profile from the FDR parameters and then discuss the determination of the actual topographic profile from the SRTM data. Next, the process of comparison of both terrain profiles needs to be described. Finally, the case study that motivated the development of the technique is briefly presented, followed by a discussion of the use of the technique for validation of trajectories obtained by FMS (flight management system) coordinates.

Terrain profile—altitude parameters

This section describes the determination of the terrain profile from altitude parameters recorded in the FDR, hereafter referred to as *altitude profile*. According to airplane flight recorder specifications, there are two distinct sources for altitude information on a commercial aircraft recorder: static pressure altitude and radio altimeter. Pressure altitude is the height of the aircraft above sea level derived from the measurement of the static pressure, assuming a standard atmosphere. The value of the static pressure is associated with a pressure altitude value by means of the international standard atmosphere (ISA) model. In turn, the radio altimeter measures height above terrain by means of electromagnetic waves that are transmitted toward the ground. This device transmits a radio signal toward the ground and measures the time delay to the reflected return signal. Commercial aircraft equipped with both systems are required to record both pressure and radio altitude parameters in the FDR.

Usually, the pressure altitude parameter is greater than the radio altitude parameter, except when the airplane is operating on an aerodrome located below mean sea level. Therefore, the simple subtraction of the radio altitude from the pressure altitude yields the terrain profile. The principle is illustrated in Figure 1. The pressure altitude measures the aircraft altitude with respect to a predetermined reference (usually the sea level) whereas the radio altimeter measures the aircraft altitude with respect to the terrain beneath; the subtraction results in the terrain profile

For the scope of this technique, the numeric value of the terrain elevation is not critical, but its shape is so that it can be compared to the actual topographic outline later. It is important to note that the radio altitude parameter is required to be recorded up to the elevation of 2,500 ft above ground (FAA, 2010). Therefore, the altitude profile cannot be determined when the airplane is flying above that.

Shuttle Radar Topography Mission

The Shuttle Radar Topography Mission (SRTM) that flew in February 2000 was an initiative to obtain a high-resolution digital elevation model of the earth. The project was a joint endeavor of the National Aeronautics and Space Administration (NASA), the National Geospatial-Intelligence Agency, and the German and Italian space agencies. It used dual radar antennas to acquire interferometric radar data, processed to digital topographic data at 1 arc-sec resolution.

The space shuttle *Endeavour* was equipped with the radar system and flew

Figure 3. Sequence of geographical coordinates (gray dots) defining the prolonged centerline calculated from a point on the runway. This sequence can then be used to calculate the SRTM terrain profile.

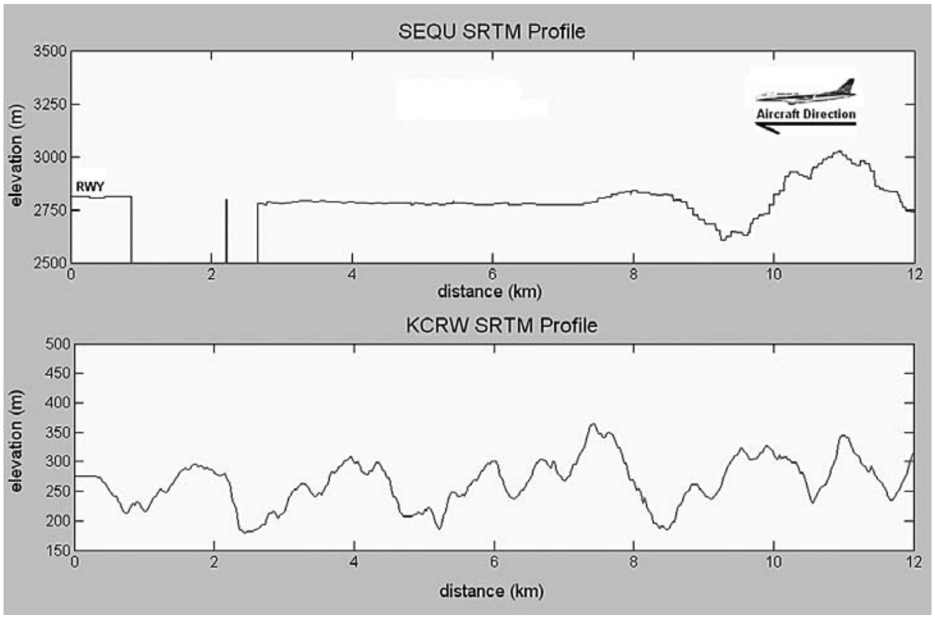

Figure 4. Comparison of two different terrain profiles. Top, profile from 3 arc-sec resolution SRTM data. Bottom, profile from 1 arc-sec resolution data. On both plots, the runway is located in the leftmost section of the graph.

for 11 days around the planet. Although the data were originally collected with 1 arc-sec resolution, the results were made public with either 1 or 3 arc-sec resolution. Only the United States has access to the higher 1 arc-sec resolution. The rest of the planet is presented with 3 arc-sec data. In practical terms, 1 arc-sec data correspond to a distance of approximately 30 m between adjacent samples, whereas 3 arc-sec data correspond to a distance of approximately 90 m.

Elevation data are presented on thousands of tiles, with each tile covering a square area of 1 latitude degree in width and 1 longitude degree in height. Each tile is formatted as a two-dimensional array whose elements are 16-bit signed integers. Figure 2 shows a schematic view of a portion of an SRTM tile of 1 arc-sec resolution.

SRTM data also contain occasional voids due to several different causes, such as shadowing, phase anomalies, or other radar-specific reasons. Elevation voids are flagged with the value -32768. Naturally, the presence of data voids is a factor that might impair the use of the terrain profile technique.

Terrain profile—SRTM

To determine the terrain profile from the SRTM data, it's necessary to know the final approach trajectory in terms of geographical coordinates (i.e., only latitude and longitude parameters). These coordinates can be considered the projection of the actual aircraft trajectory onto the ground. In other words, this projection is a rough trajectory that will be used to obtain a valid trajectory. The projected trajectory is necessary so that it's possible to look inside the SRTM file and then determine the terrain elevation of each of its coordinates. The resulting elevation data make up the SRTM terrain profile.

However, the technique would not be necessary if these aforementioned coordinates were known in the first place. Fortunately, for the cases in which few parameters are available, it's relatively easy to determine a sequence of latitude/longitude pairs that correspond to the flight phase whose profile one wants to determine. For flight phases in which the aircraft is aligned with a runway (either in final approach or initial climb), it's necessary to determine a sequence of geographical coordinates that corresponds to the prolonged runway centerline. To calculate these coordinates, it is possible to use the so-called *great circle distance* equations starting from an arbitrary point located on the runway centerline. Figure 3 depicts a sequence of coordinates showing the prolonged centerline. The distance between the points depends on the resolution of the SRTM data being used.

For the cases in which the aircraft is not aligned with a runway, it's possible to find a reference on the ground that might be related to the aircraft trajectory, such as a VOR/DME station that the aircraft was using as a navigation aid. In theses cases, determining the coordinates might be more difficult because more complex calculations are required.

Once the coordinates have been determined, it's necessary to determine the elevation of each of the coordinates by looking into the SRTM file. The tile that contains the phase of flight must be used. As previously mentioned, the SRTM file is a grid composed of elevation samples separated by 1 or 3 arc-sec of degree. Since the trajectory coordinates do not necessarily coincide with the points in the SRTM grid, it's necessary to either interpolate the elevation samples or find the nearest match in the SRTM grid. For the purposes of this technique, the nearest match approach proved to be adequate.

Figure 4 shows the SRTM terrain profiles of two distinct airports. The top one is the terrain profile obtained by extending the Runway 17/35 centerline toward the south at Mariscal Sucre International Airport (SEQU), Quito, Ecuador (3 arc-sec resolution). The bottom one is the terrain profile obtained by the extension of the Runway 05/23 centerline toward

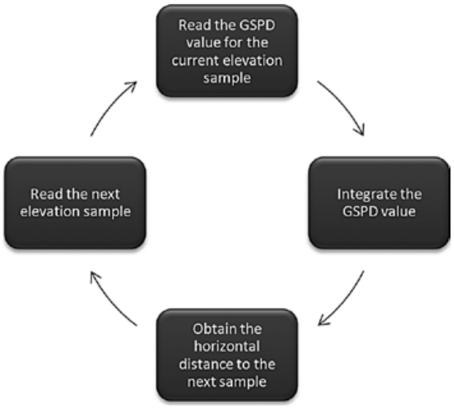

Figure 5. Process of determining the horizontal distance. GSPD is the ground speed parameter.

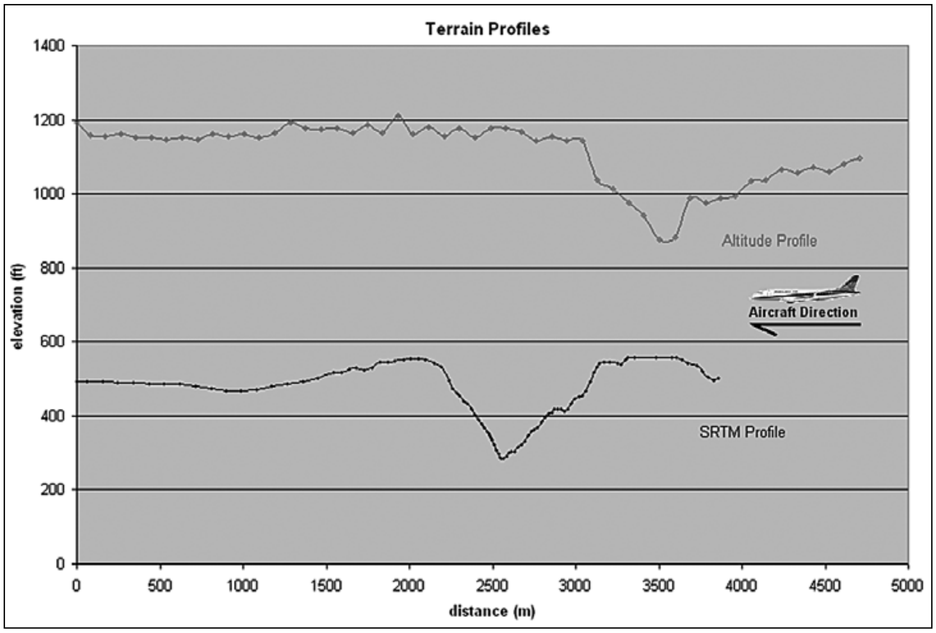

Figure 6. Comparison of altitude and SRTM profiles of the occurrence flight. Both depict similar features that are displaced from each other.

the northeast at Yeager Airport (KCRW), Charleston, W.Va. (1 arc-sec resolution). Notice that the 3 arc-sec resolution profile depicts sharp edges where the relief is irregular. This effect is a consequence from the lower 3 arc-sec resolution and is a factor that hampers analyses in regions outside the United States. Furthermore, in the 3 arc-sec profile, it's possible to see the aforementioned data voids between 0 and 4 km from the runway. The occurrence of voids, however, is not restricted to lower resolution data only.

In addition to low resolution data and the presence of data voids, other circumstances may cause SRTM profiles not to provide useful information to be compared with the altitude profile. SRTM data do not render the best results when applied in regions with characteristics of flat terrain or flights above the sea. Additionally, as the SRTM data were originally collected in the year 2000, many relief aspects may have changed since then as many of its characteristics are subject to human activities or environmental processes (e.g., constructing new buildings, earthquakes, etc.).

Comparison of terrain profiles

Once both SRTM and radio altimeter profiles have been determined, it's necessary to plot them both as a function of the horizontal distance from a given reference. Plotting the SRTM profile as a function of distance is quite simple, as the geographical coordinates of the elevation samples are known, and consequently the distance between them can by obtained by great circle equations. To obtain the distances between the elevation samples of the altitude profile, the analyst must consider the aircraft ground speed registered in the FDR, which then makes it possible to determine the horizontal distance between the elevation samples obtained from the altitude parameters. One point is chosen as the distance reference and from that point, the next points are calculated, one after the other. By integrating the groundspeed parameter in time, it's possible to obtain the traveled distance between two elevation samples. Figure 5 shows the process of calculating the horizontal distance between the elevation samples so that the altitude terrain profile can be plotted as a function of that distance.

An important aspect to consider is the timing between samples of the involved parameters, as the integration process depends on the association between the ground speed and the altitude parameters. For example, if the sample rates of these parameters do not match, it's necessary to carefully select which samples will be used in the integration process. Otherwise, the analysis might not be as accurate. It's important to note that the horizontal distance is not necessarily a distance measured along a straight line. Even if the trajectory is curvilinear, the method is still applicable because the elevation profile is a sequence of terrain elevation samples measured along a sequence of points that are not necessarily aligned. Therefore, only the distance between samples matters, not the relative bearing between them. The importance of the horizontal distance lies on the fact that it defines if the altitude profile seems distorted ("stretched" or "shrunk") when compared with the SRTM profile.

It's possible, however, that the ground speed parameter is not available in the FDR. In that case, it's necessary to use the recorded airspeed, making the appropriate wind corrections.

Once the horizontal distance between the altitude samples is determined, the profiles are plotted and that plot will reveal that both of them show similar relief features, such as hills and valleys. As the SRTM profile was assumed to begin in an arbitrary point (see section "Terrain profile—SRTM"), it's likely that the profiles will be displaced from each other. That displacement will define the horizontal distance from the arbitrary point and the actual point. For example, during a landing, the altitude profile might begin at the point the aircraft touches the ground, and the SRTM profile begins at the touchdown aiming point, located approximately 1,000 ft from the runway threshold. In this case, the displacement between both profiles corresponds to the distance between the arbitrary point in the SRTM profile and the actual touchdown point on the runway.

Case study—runway excursion

This case study describes how the terrain profile technique was applied in the inves-

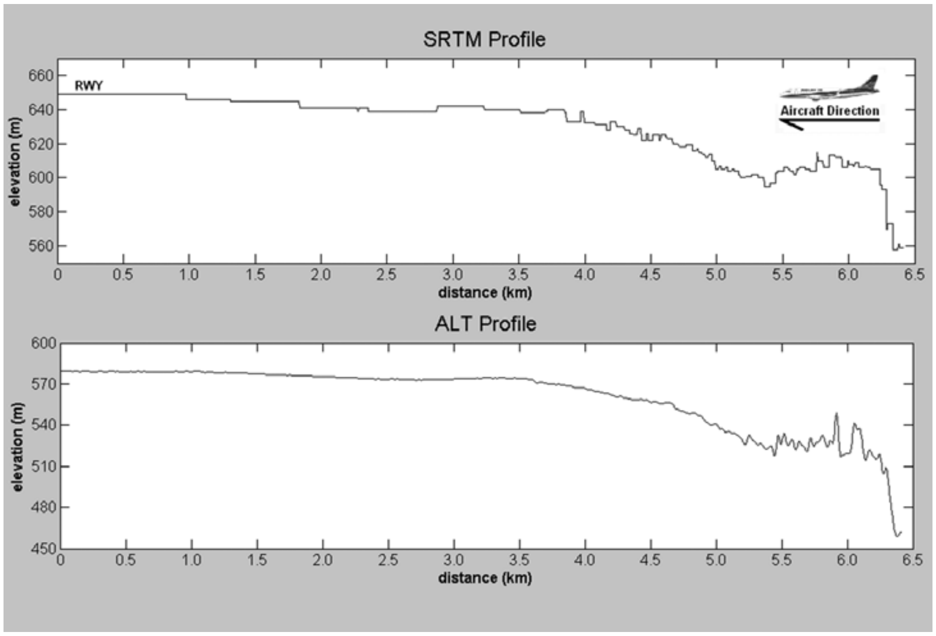

Figure 7. Comparison between SRTM and ALT terrain profiles. Notice that both depict the same relief features without displacement. The runway is located in the leftmost section of the plot.

tigation of a runway excursion involving an Embraer aircraft. The approach took place during adverse weather conditions. The occurrence aircraft did not record latitude and longitude parameters. Furthermore, although the airport did have ILS antennae, the corresponding frequency on the navigation radio was not set by the flight crew. Therefore, the ILS deviation parameters were not available for analysis as well. Moreover, although the aircraft did record the groundspeed parameter, it was not possible to use this parameter to determine the touchdown point because the FDR recording ceased while the airplane was in motion.

The occurrence took place at an airport with hilly terrain near the runway, and this motivated developing the technique. Both altitude and SRTM terrain profiles were determined following the steps described in the previous sections. The chosen arbitrary point where the SRTM profile begins was the touchdown aiming point, whereas the point in which the altitude profile begins is the instant at which the aircraft air/ground logic indicated the aircraft had landed. Figure 6 shows both profiles.

The profiles are very similar in shape but are displaced from each other. The terrain features occur “before” in the SRTM profile. That is, for a given terrain feature, its horizontal distance from the origin is smaller for the SRTM profile. This indicates that the arbitrary point in which the SRTM profile begins is located forward (in the direction of the runway threshold) the point at which it should actually be. By comparing the profiles, it was determined that they were displaced by 1,036 m. That discovery showed that the aircraft actually touched down approximately 4,400 ft from the runway threshold of a 9,700-ft runway and the discovery ultimately helped investigators to better understand the occurrence and the involved factors.

Trajectory validation

So far we’ve discussed how the terrain profile analysis can be used for trajectory determination. However, even for cases in which more parameters are available and the trajectory is known, the technique can be a useful tool for cross-checking data. For example, cases in which FMS latitude and longitude are available in the FDR, the altitude and SRTM profiles can be plotted together to ensure that these geographic coordinates do not present displacement error in the direction of motion. Figure 7 shows the comparison of both profiles using this technique during the landing of an E-Jet at Sao Jose dos Campos Airport, Brazil. The profiles match, and thus the trajectory error is smaller than the SRTM data resolution of 3 arc-sec, approximately 90 m.

Summary

We have presented a technique based on the comparison of terrain profiles obtained from two different sources. The technique proved to be useful in the investigation of a runway excursion in which the FDR data alone could not be used to determine the touchdown point. The merit of the technique, therefore, lies in its capacity to correlate the aircraft trajectory with the ground when the available data do not allow it based on other analyses. Furthermore, we discussed how the technique can be used to perform a validation of trajectories obtained from other FDR parameters.

Yet the tool also has its restrictions. As mentioned, the SRTM profile does not provide adequate information when applied to flat terrain or water. Moreover, the altitude profile cannot be determined when the aircraft reaches 2,500 ft above ground level. All these restrictions must be considered carefully prior to drawing any conclusions from the application of this technique.

Nevertheless, as investigators are more and more often required to timely respond to occurrences with accurate conclusions, it’s always desirable to have an additional means to extract useful information from flight data, further enhancing their ability to adequately investigate incidents or accidents. If applied correctly, this tool is a step in that direction. ◆

Acknowledgments

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Useful Human Factors Invest

Investigation of a 2007 commercial Beech King Air medical evacuation flight accident required use of s

By David Ross, Regional Senior Investigator, Operations, Transportation Safety Board of Canada

(This article is adapted, with permission, from the author's paper entitled Useful Human Factors Investigative Techniques: A Case Study of a Fatal King Air Accident in Canada *presented at the* ISASI *2010 seminar held in Sapporo, Japan, Sept. 6–9, 2010, which carried the theme "Investigating ASIA in Mind—Accurate, Speedy, Independent, and Authentic." The full presentation, including cited references to support the points made, can be found in* ISASI Proceedings 2010 *on the ISASI website at www.isasi.org.—Editor)*

On the evening of Jan. 7, 2007, a commercial Beech King Air medical evacuation flight inbound to Sandy Bay, Saskatchewan, abandoned its landing attempt, but the aircraft did not climb sufficiently and collided with trees beyond the end of the runway. While all four occupants evacuated the aircraft, the captain died of injuries before rescuers arrived. Two passengers (medical technicians) were seriously injured, and the first officer had minor injuries. The aircraft was destroyed by fire.

This adapted article focuses on investigative methods. Some information about the occurrence is used to illustrate these methods. For full details of the occurrence, see TSB Investigation A07C0001-Collision with Terrain-Transwest Air Beech A100 King Air C-GFFN Sandy Bay, Saskatchewan, available on the Transportation Safety Board (TSB) of Canada website.

Examination of the wreckage revealed no indication of pre-impact anomalies. A cockpit voice recorder (CVR) was recovered from the wreckage and proved to be an important information source. Subsequent review of the CVR, aircraft records, and initial interviews revealed the aircraft had operated normally throughout the flight. Consequently, the investigation focused on human and environmental factors. This article addresses only human factors; see the investigation report regarding environmental factors.

The investigation team quickly became aware of multiple instances of flight crew practices that varied substantially from the procedures and policies of the air operator company. We decided investigative assistance was necessary, and an investigator from the TSB Human Performance Division was assigned. With this addition to the investigative team, we continued to review the CVR and conduct interviews.

First, we verified and documented the variation of crew practices on the occurrence flight from policies and procedures. At the end of this process, we were concerned that the variations in practices could extend beyond the occurrence crew. Consequently, we expanded the scope of the investigation to examine organizational factors in more detail.

Interview survey

One month after the accident, we interviewed seven pilots who operated the company's two King Air aircraft. We also interviewed the pilots' supervising managers.

Using the record of variant crew practices from the occurrence flight, we developed an informal survey of 13 questions to examine pilot knowledge of and compliance with the company's procedures and policies. This was consistent with TSB investigative guidance to examine the 4 P's of philosophy, policies, procedures, and practices.

The survey was conducted by asking questions at appropriate times during interviews. Interview subjects were not aware of the survey, and the sequence and timing of questions varied between interviews. The interviews were conducted by operations and human performance investigators and were recorded and transcribed. From the transcripts, we developed a survey summary. The following are two examples of the responses to survey questions.

First, the company frequently had flights operating on short runways much like the one involved in this occurrence. We needed to know the extent to which pilots used aircraft performance data. The survey summary showed that most of the pilots interviewed did not make landing performance calculations required by policy, while some others rarely did so (see Table 1). This information led directly to a finding regarding causes and contributing factors: the crewmembers did not assess the aircraft performance and did not identify runway length as a threat.

Second, the Sandy Bay aerodrome did not have any instrument or visual vertical guidance system for pilots and also did not have any communications facilities. Consequently, company policies and procedures prohibited straight-in approaches and required pilots to visually inspect the runway before landing. We needed to know whether pilots were aware of and complied with these policies. The survey summary showed that half the pilots interviewed were not aware of this prohibition, and the remainder reported flying straight-in approaches when prohibited (see Table 2).

This interview survey proved to be a very effective data collection method. Formatting the data in a summary documented the extent of pilot non-compliance, which supported our finding that substantial and widespread deviations from standard operating procedures had developed and persisted within the company's King Air operation.

During interviews with flight operations

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igative Techniques

everal methods for investigating human factors to properly collect and analyze relevant information.

Position	Answer
Training Captain	Performance charts not used.
Training Captain	Performance charts not covered in ground school.
Captain	Performance charts not used.
First Officer	Used charts during training, rarely used them since.
First Officer	Used charts during training, rarely used them since.
First Officer	Not asked.

Table 1: Survey Summary—Landing Performance Calculations

Position	Answer
Training Captain	Aware of policy. Thinks compliance good with occasional intentional deviations in visual conditions.
Training Captain	Likes to circle, but has done straight-in approaches.
Captain	Unaware of policy. Flies straight-in approaches if winds known.
First Officer	Unaware of policy. Thinks decision is at captain's discretion.
First Officer	Unaware of policy.
First Officer	Aware of policy. Thinks compliance is good with occasional intentional deviations.

Table 2: Survey Summary—Straight-in Approaches

managers, investigators also asked questions regarding supervisory practices and knowledge of pilot compliance with policies and procedures. This revealed that supervisors were unaware of the pilot practices that deviated from policies and procedures.

While the interview survey was very useful, one negative consequence was that it substantially increased investigative workload, because many more interviews were conducted compared to other TSB investigations of similar occurrences.

Time lines

A time line is a useful tool to help investigators understand why people did what they did. According to S. Dekker (2006), "If you want to begin to understand human error,…a good starting point is to build a time line."

Establishing and documenting a sequence of the occurrence events is part of the TSB's integrated safety investigation methodology (ISIM) and is a normal TSB investigative function. ISIM is embedded in the TSB's transportation investigation information management system (TIIMS) through the use of a number of software tools for documenting and analyzing time lines.

In this investigation, high-quality data from the CVR enabled investigators to develop a detailed occurrence sequence of events. However, not all events were recorded on the CVR, and many safety issues involved events that should have happened but did not. The occurrence time line was used to integrate events identified from all sources and to identify times when the non-events should have occurred. The occurrence time line was extremely useful in determining the sequence of events, and aided us in understanding the flight crew's behavior in the context of the many underlying factors.

In addition to the events during the accident flight, the investigation also examined events at two organizational levels: the air operator company and the regulatory oversight agency. Time lines were developed to establish the sequence of events within both of these organizational levels and to help investigators understand the interrelationships between the levels.

The organizational time line for the company was useful in that it organized supervisory activities into chronological order, again with linkages to underlying factors. This enabled a cross-reference to the crewmember time lines, helping investigators to better understand the company's supervisory capabilities and limitations.

The organizational time line for the regulator helped document events we had identified in chronological order. However, this time line was of low resolution and dealt with events that had occurred up to 2 years previously. The limited number of events we identified were specific to investigative areas of interest, and, to investigators, these events took on the appearance of a linear chain of events. In reality, these events were far from linear. Hundreds of other events we did not know about created a complex organizational context. Within this context were the selected events we studied.

Our recommendation is to use such a time line with caution regarding hindsight bias and to work to understand the overall organizational context.

Conceptual deconstruction

Portions of the analysis in the investigation report discussed three broad concepts: crew resource management (CRM), situational awareness, and safety management systems (SMSs). We were unsuccessful in our initial attempts to develop convincing arguments to support our findings in these areas. This resulted from describing how the occurrence events indicated problems with each concept as a whole, with investigators expecting that our findings were, to a large extent, self-evident. However, as Dekker (2006, 2002) points out, we had made a "leap of faith" by using the categories as labels, and we had not clearly demonstrated that the facts led to our conclusions or that the problems identified had contributed to the occurrence.

Once the draft report had been reviewed externally, it was obvious from reviewer comments that our initial analysis needed to be revised. The approach taken was to deconstruct each of these three broad concepts into smaller, more manageable components.

CRM

The definition of CRM that we used is the use of all human, hardware, and information resources available to the flight crew to ensure safe and efficient flight operations. In this occurrence, among the information resources available to the crew was extensive operational risk management guidance in the company's flight operations manual and standard operating procedures.

Canada requires that flight crews operating airline category aircraft with 20 or more passenger seats must receive CRM training. However, crews operating smaller aircraft, such as the King Air, are not required to receive such training. The Commercial Air Services Standards of the Canadian aviation regulations lists eight CRM components for which training must be provided to airline category pilots. Several of these components were used in the revised analysis to better describe the problems that existed on the occurrence flight and within the company's King Air operation. Let's look at the CRM components of problem solving and decision-making.

Problem solving is a CRM component listed in the training requirements. When this portion of the analysis was revised, we used a number of examples of crew behavior as premises to support our argument that their problem solving was ineffective.

The destination of the occurrence flight was a 2,880-foot gravel runway. Post-accident calculations showed the landing distance on a bare and level paved surface was 1,600 ft, resulting in a touchdown zone length of 1,280 ft. However, compacted and loose snow contaminating the runway would increase the landing distance and reduce the touchdown zone length.

Although company procedures required pilots to make pre-flight aircraft performance calculations and to consult landing charts for contaminated runway operations, the occurrence crew did not make any landing performance calculations. Both pilots had previously flown into Sandy Bay without incident, and they likely expected this flight to be little different from previous flights. Additionally, the interview survey of other pilots showed they, too, did not normally conduct aircraft performance calculations. We concluded that pilot practice across the company's King Air operations was to base expectations of aircraft performance on past experience.

The occurrence crewmembers did not assess the aircraft landing performance or identify runway length as a threat. Consequently, they did not discuss and agree on a point at which a safe landing was no longer possible, and they were unprepared to make an informed and timely go-around decision as a crew.

Decision-making is a second listed CRM component for which training is required. We again used examples of occurrence crew behavior to enhance our argument that decision-making was ineffective.

One example occurred during the after-start check, when the captain designated the first officer as the pilot flying for the leg and the first officer concurred. This was contrary to one company policy requiring the captain to be pilot flying on the first leg of the day, and a second policy requiring captains to conduct landings on runways shorter than 3,500 ft. The investigation could not determine why this decision was made. A result of this decision was that the less experienced crewmember was the pilot flying the approach to Sandy Bay.

A second example of ineffective decision-making is the occurrence crew's conduct of the final approach and go-around (see Figure 1). These portions of the flight also serve as an example of ineffective crew problem solving. The crew was conducting a non-precision instrument approach with the first officer flying the aircraft. Both crewmembers acquired visual reference with the runway about 4 miles from the threshold. Subsequently, the captain identified that the aircraft was high on the approach and began coaching the first officer. The first officer made an unassertive suggestion that they conduct a go-around, but the captain rejected the suggestion and continued coaching the first officer into the landing flare. In the flare, the captain decided to initiate a go-around, but his communication of this decision to the first officer was non-standard and did not have the desired effect of triggering the correct sequence of go-around actions required.

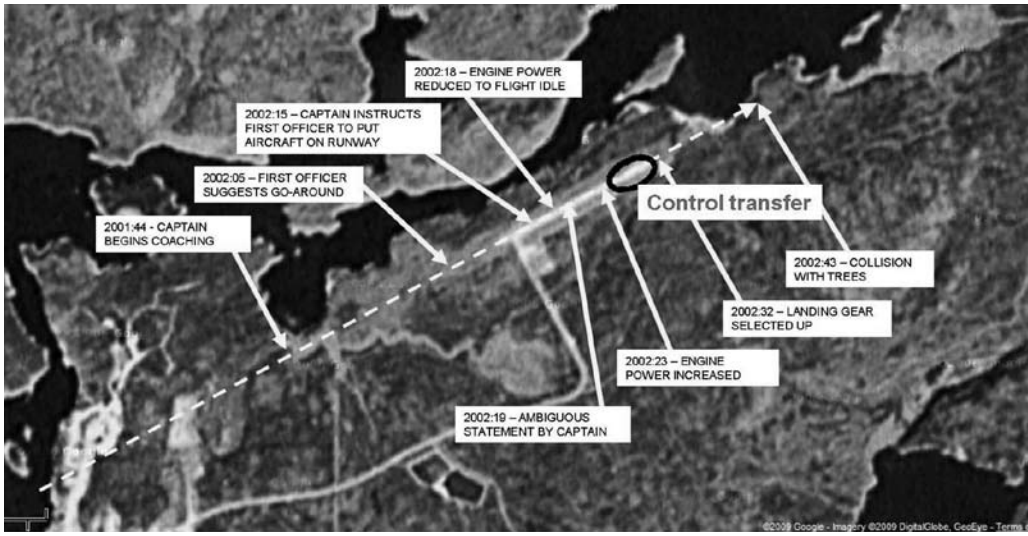

Figure 1. Sequence of events.

All of these examples had been included in the factual section of the initial draft report. However, discussing them in the revised analysis in the context of specific CRM components provided a more convincing argument to support our conclusions that the flight crew exhibited ineffective CRM and that the ineffective CRM contributed to the occurrence.

Situational awareness

A second broad concept the investigation examined was situational awareness.

The company was working toward, but had not yet received, regulatory approval to conduct GPS approaches. The company's aircraft were equipped with GPS certified for instrument approaches, and flight crew training was being developed. The occurrence crew used the GPS to provide distance-to-go to the aerodrome identifier waypoint, and this practice was also used by the company's other King Air pilots.

However, the geographic coordinates of an aerodrome identifier waypoint are those for the aerodrome geometric center. In Sandy Bay, this point was the center of the runway, equidistant from both ends of the runway.

We wanted to assess the effect on flight crew situational awareness of using GPS distance-to-go to the center of the runway rather than the threshold. The actual distance to the threshold was about ¼ nautical mile less than the distance to the aerodrome waypoint coordinates, and our hypothesis was that this may have contributed to the aircraft being high on the final approach.

We used a model of situational awareness described by N. Brunelle, in her paper "Conversations in the Cockpit: Pilot Error or a Failure to Communicate?" presented at ISASI's 2008 seminar in Halifax, Canada, wherein the concept is divided into five elements. We focused on the spatial/temporal element, in particular the ability of the crew to anticipate the projected flight path of the aircraft.

We concluded that the crewmembers were likely unaware of the ¼ mile difference between the depicted GPS distance and the distance to the runway threshold. We were unable to determine whether this contributed to the aircraft being high on final approach. However, both crewmembers had visual contact with the runway for at least 2 minutes before the landing attempt, and the captain did identify visually that the aircraft was high on approach and took corrective action. Therefore, the crew was able to accurately predict the projected flight path of the aircraft during the final approach.

Our examination of situational awareness did not extend beyond this issue. However, the ability to divide the overall concept into smaller elements helped investigators determine that the use of GPS distance-to-go had not contributed to the occurrence.

SMS

A third broad concept we examined was SMS.

In 2005, the Canadian aviation regulations were revised to require specified organizations to implement an SMS. The occurrence air operator company was required by the new regulations to have an SMS because it operated three airline category aircraft. Implementation of the SMS was being done in four phases under the oversight of Transport Canada.

The regulations and Transport Canada guidance material divide an SMS into six components. Three of the components are further divided into elements for a total of 17 SMS elements.

In January 2007, at the time of this occurrence, the company was in phase 2 of implementation. During phase 2, among other SMS elements, the company was implementing a non-punitive reporting policy; a reactive reporting system; and reactive investigation, analysis, and risk management processes. Proactive processes would be implemented during phase 3. The company did not have a fully functioning SMS and was not required to have one until the completion of phase 4, in September 2008.

We limited our examination of the company's SMS to only those elements being implemented during phase 2.

We determined that the company's immature SMS had not detected some previous occurrences involving the accident crew or many underlying factors identified as contributing to the accident. From this, we concluded that the company's reactive reporting system was not yet functioning.

In November 2006, 6 weeks before the accident, the company's SMS did detect and investigate a regulatory infraction involving the accident crew. We examined the reactive investigation, analysis, and risk management processes used by the SMS in this instance.

We determined that the company's investigation was well documented but was limited in scope. The company SMS analysis focused solely on the crew and did not identify underlying supervisory and operational control deficiencies. Short-term corrective action taken by the company was an immediate suspension without pay for 2 weeks for the captain and 1 week for the first officer. Long-term corrective action included both a safety directive to flight crews regarding the numerous flight operations regulatory violations incurred by the company and pilot meetings to be held at each base to discuss the violations.

Follow-on action was to be a line check of the crew to assess compliance with regulations and standard operating procedures. The captain and first officer were scheduled to fly together only once in December 2006 following their suspensions; consequently, the company intended to conduct a line check in January 2007 but had not yet scheduled it when the accident occurred.

The company's SMS was immature and still under development, and this was reflected in the SMS investigation of the November 2006 incident. We concluded that the company's SMS was not yet capable or expected to be capable of detecting, analyzing, and mitigating the risks presented by the hazards underlying this occurrence. This finding was listed with "Other Findings," which are intended to clarify a point of ambiguity or controversy. This issue had not contributed to the occurrence.

We were also interested in the company's use of punitive suspension from duty when an SMS non-punitive reporting system was being implemented. Our investigation revealed that, in the fall of 2006, a consultant audited the company's operations and found, in part, that the company's management response to repeated flight crew regulatory infractions was insufficient and recommended that the company implement a disciplinary policy. The company initially used unpaid suspension from duty as punishment, with a subsequent revision to fines of 10 percent of monthly salary for a first offense and 20 percent of monthly salary for a second offense, with no suspension from duty. Within 2 months of implementation of this policy, six company pilots had been disciplined, including the accident crew.

Our investigation determined that use of punitive action can substantially impair safety reporting systems. We made a finding as to risk that, in an SMS environment, inappropriate use of punitive actions can result in a decrease in the number of hazards and occurrences reported, thereby reducing effectiveness of the SMS.

The ability to divide the overarching SMS concept into smaller, more manageable elements proved to be quite helpful to our investigation. We were able to more effectively demonstrate that the facts supported our conclusions.

Local rationality

Hindsight bias strongly influenced initial attempts to understand the many deviations from policies and procedures that occurred during the accident flight. At that time, the focus of the investigation was on explaining what should have been done but was not. This approach influenced the analysis and findings in the initial draft report. When external reviewers provided comments on the draft report, it became clear that revisions were necessary.

During the post-review phase, our focus shifted to explaining why the crewmembers behaved as they did, rather than pointing out what they should have done but did not. To help us do this, we applied the principle of local rationality, as put forth by D. Woods and R.I. Cook in their "Perspectives on Human Error: Hindsight Biases and Local Rationality."

As Woods and Cook noted, people do not go to work with the intent of causing an accident. Their decisions and behavior make sense to them in the context of their knowledge, circumstances, and goals. Although there may be limited information available, their situation may seem ambiguous, or they may have multiple conflicting goals, they make the best of what they have in order to get their work done.

Our challenge was to understand the world as the crew perceived it, in order to understand how they made sense of the situation. We used this approach to revise the analysis of the transfer of control that occurred during the go-around.

Procedures for clear and consistent verbal communications prevent confusion between pilots as to who has control of the aircraft, and the company had a control transfer procedure that was standard throughout its fleet.

However, the investigation revealed that the captain and first officer occasionally used a non-standard transfer of control practice that varied substantially from the procedure specified in the standard operating procedures. This practice resulted from the captain's mistrust of the first officer's ability to land the aircraft.

During previous flights, the captain had taken control of the aircraft from the first officer on numerous occasions, sometimes doing so using the phrase in the standard operating procedures, "I have control," sometimes using non-standard verbal phrases, and sometimes without making any verbal statement. In instances when the captain took control without making any verbal statement, the first officer's practice was to release the controls upon sensing pressure from the captain's control inputs.

Our problem was that the captain had been fatally injured, and we were unable to confirm that he had, in fact, taken control from the first officer during the go-around. In the initial draft report, our analysis of this control transfer was inconclusive. Applying the principle of local rationality helped us to revise our analysis.

As previously discussed, the flight was high on final approach, the first officer was the pilot flying, and the captain coached the first officer into the landing flare. The captain decided to initiate a go-around and communicated this decision to the first officer with a non-standard and ambiguous statement.

Having advised the first officer of his intent to conduct a go-around, the captain would have expected the first officer to advance the power levers. However, because the captain's statement was non-standard and ambiguous, the first officer was unsure of the captain's intentions and did not initiate the go-around by advancing the power levers. Four seconds after communicating his go-around decision, the captain, likely feeling a sense of urgency by now, advanced the power levers himself.

The captain almost certainly took this action because it was clear to him that they could not land safely on the remaining runway, and the first officer had not responded to his communication of his go-around decision.

We examined four possible scenarios of aircraft control during the go-around:

- The first officer was in control.
- Both pilots were attempting to control the aircraft.
- The captain was in control.
- Neither pilot was in control.

Immediately after the captain had advanced the power levers, the first officer perceived pressure on the control column and observed the captain's hand on the control column. Believing the captain was taking control without making any verbal statement, as had occurred on previous flights, the first officer released the control column, also without making any verbal statement, using the non-standard practice they had employed on previous flights.

The first two scenarios listed above did not occur because the first officer released the control column.

On previous flights, the captain had taken control from the first officer both on approach and during landing. Given the captain's mistrust of the first officer's ability to land the aircraft, the lack of response from the first officer to the captain's ambiguous go-around communication, and the fact that the remaining runway was insufficient to land safely, we concluded that it was very likely that the captain did take control from the first officer and became the pilot flying for the remaining 20 seconds of the flight.

We also concluded that the scenario in which neither pilot was controlling the aircraft was very unlikely.

The conclusions we reached in the revised analysis made sense to us in the context of the crew's local rationality. These pilots did things for reasons that made sense to them at the time, given their circumstances, knowledge, and goals.

Conclusions

- Conducting a survey within interviews proved to be a very useful means of obtaining information.
- Use of a time line was very helpful to analyze and understand the occurrence sequence of events and underlying factors. An organizational time line for company managerial activities was also helpful.
- The regulator time line was of low resolution but was useful to establish chronological sequencing. However, it actually introduced confusion because of the inability to portray the complex organizational context within which decisions and actions were taken. Such a time line should be used with caution.
- Arguments regarding deficiencies in concepts such as CRM may not convince the reader. Dividing the concepts into smaller components will provide a trail to your conclusions that the deficiencies existed and contributed to the occurrence.
- The principle of local rationality helped us to understand why the flight crew's decisions and actions made sense to them, and to avoid the negative effects of hindsight bias. ◆

ISASI 2011 Registration Opens

Registration is now open for ISASI 2011, the Society's 42nd annual international conference on air accident investigation to be held in Salt Lake City, Utah, USA, from Monday, September 12 through Thursday, September 15. The conference theme is "Investigation—A Shared Process." The seminar's website is accessible through the ISASI website, www.isasi.org, and is now accepting registrations for both the conference and hotel accommodations. The seminar program registration fee (in U.S. dollars) before Aug. 15, 2011, is member, $550; non-member, $600; and student member, $200. A one-day pass is $200; tutorial only, $150; and companion, $325. If registration is made after August 15, the fees are members, $600; non-members, $650; and student member, $225. A one-day pass is $225; tutorial only, $175; companion, $350. The cost of a single event is—Welcome reception, $50; Tuesday night dinner, $100; and awards banquet, $100.

The seminar hotel is the Salt Lake City Marriott Downtown located in the heart of downtown. The conference room rate is US$175, based on single or double occupancy. Reservations must be made through the noted website link to ensure the seminar rate. Reservations may be made as early as September 8 and extended to September 17. This rate includes daily room Internet access and use of the pool, sauna, hot tub, and fitness center.

The hotel is 15 minutes or a US$20 cab fare from the Salt Lake City International Airport. Public transportation is readily available, as is XPRESS Shuttle of Salt Lake City, which provides hotel service for about $8 per person. Another option is Quicksilver Private Transportation Services.

Delta Air Lines is the official airline of ISASI 2011. The airline is offering a discount on roundtrip tickets that originate in the U.S. or Canada and have a base fare greater than $120. To receive the discount, customers should call reservations at 1-800-328-1111 and provide the group discount code of NM74B. The discount is valid for travel between Sept. 9, 2011. and Sept. 18, 2011.

Full conference details may be found on the ISASI website or in the Forum January-March 2011, page 26. Registration information is also available via e-mail: avsafe@shaw.ca or via telephone: 604-874-4806. ◆

Air Astana Hosts 39th Reachout Workshop

Air Astana hosted the 39th ISASI Reachout Workshop on incident investigation and safety risk management in Almaty, Kazakhstan, February 7-11. The workshop was held at the training facilities of Air Astana and was attended by 18 participants. Gerhard Coetzee, senior vice-president of corporate safety and quality Assurance of Air Astana, attended the closing ceremonies.

The 18 participants from Air Astana represented all operational areas, including pilots (involved in company safety management), maintenance and quality engineers, aviation security personnel, and safety department personnel. Some participants were from other Air Astana stations, such as the capital Astana. All received ISASI completion certificates.

Workshop instructors were Caj Frostell and Mike Doiron. Their training material, which each participant received, was comprised of paper handouts and a CD with published manuals and booklets that provided considerable background materials for future reference. In addition, ISASI membership forms were made available to the participants. The program included several interactive case studies and working group assignments

Being a corporate member of ISASI, the management of Air Astana was pleased to welcome ISASI activities at their home base. Coetzee and the participants were most appreciative of ISASI for bringing the Reachout Workshop to Almaty and to the instructors for sharing their knowledge and experience. Coetzee mentioned that ISASI has certainly found a new group of admirers in his staff and welcomed ISASI back to Almaty on another occasion. ◆

Participants at the 39th ISASI Reachout Workshop in Almaty, Kazakhstan, hosted by Air Astana.

SER Chapter Meets in Key West, Fla.

The Southeast Regional Chapter of ISASI held its annual meeting on February 26 in Key West, Fla. Thirty-one persons attended, including 12 student members. Robert Rendzio, the chapter president, and Dan McCune, vice-president/treasurer, opened the meeting and welcomed all to the relaxed resort area of Key West.

Anthony Brickhouse of Embry-Riddle Aeronautical University was the first speaker of the day and talked about mental health aspects of aircraft accident investigation: protecting the investigator. He discussed the different levels of stress experienced by investigators during aircraft accident investigations and emphasized that there is currently no official training for the mental health of investigators, He asked the question: "How can we diagnosis mental stress?" His hope is that one day there will be an examination of the feasibility of developing an annual mental conditioning program in order to prevent acute stress disorder and post-traumatic stress disorder (PTSD).

Charley Pereira from Transportation Safety and Security Consulting, Inc. spoke next regarding low airspeed alerting systems and how a modern system consists of visual and aural alerts well before activation of the stall protection system or natural aerodynamic stall. He discussed how in October 2002 Sen. Paul Wellstone died tragically when the Beech King Air he was in crashed due to low airspeed. He informed the group that in December 2003 recommendations were made to require low airspeed altering system be installed in aircraft. Pereira mentioned that it took until February 2010, but new low airspeed alerting systems were recommended to the FAA. References can be made to A-10-011 and 012. And now key industry players have begun to install the warnings through TCAS systems.

Bob Watkins of the Grumman Corporation addresses the SERC meeting in Key West, Fla.

Dr. Paul Schuda of the NTSB made a presentation on the TWA Flight 800 (N93119) investigation. The Boeing 747 accident happened on July 17, 1996, and took the lives of 230 people. He discussed the headlines and conspiracy theories that went along with the event. Thanks to wreckage recovery, dispersion charts and studies, reconstruction of the aircraft, and beneficial parties to the investigation, it was determined that the most likely ignition event was a short-circuit within the empty but highly volatile center wing fuel tank. Because of this tragedy, fuel tank inerting systems have been mandated by the FAA that will reduce the amount of oxygen in the tanks, almost eliminating the risk of explosion.

The final speaker of the day was Bob Watkins of the Grumman Corporation. He provided an entertaining and informative presentation on the NASA Apollo lunar module. He began by discussing the F-14 Tomcat and the origin of its name. He discussed the pressure under which the pilots were placed and how this resulted in a crash of the first F-14. There was coverage of the specific details of the first lunar module in which a roach that climbed onboard caused a major upset and might have altered the schedule if it had not been found after exhaustive searching. He also covered the route and paths taken to land the first shuttle on the moon, and how Neil Armstrong had described the moon surface as "grey flour."

The Chapter's next spring meeting will be held in New Orleans, La. More information will be sent out regarding the 2012 meeting, at a later date. ◆

ERAU Student Chapter Is an Active ISASI Group

The student Chapter of ISASI at Embry-Riddle Aeronautical University in Daytona Beach, Fla., has been very active in promoting aviation safety and offering networking opportunities to student members. With the support of faculty advisor Anthony Brickhouse, a speaker at the 2010 ISASI Seminar in Sapporo, the student Chapter currently has 32 student members, many of whom are also members of the international Society. The current officers are Michael

ISASI Student Chapter officers are, from left to right, De Paul Sunny, Maggie Wong, Michael Gaver, and Gaston Gaber.

2010 Annual Seminar Proceedings Now Available

Active members in good standing and corporate members may acquire, on a no-fee basis, a copy of the Proceedings of the 41st International Seminar, held in Sapporo, Japan, Sept. 6-9, 2010, by downloading the information from the appropriate section of the ISASI web page at www.isasi.org. The seminar papers can be found in the Members section. Alternatively, active members may purchase the Proceedings on a CD-ROM for the nominal fee of $15, which covers postage and handling. Non-ISASI members may acquire the CD-ROM for US$75. A limited number of paper copies of Proceedings 2010 are available at a cost of US$150. Checks should accompany the request and be made payable to ISASI. Mail to ISASI, 107 E. Holly Ave., Suite 11, Sterling, VA USA 20164-5405. ◆

Speakers and Technical Papers Presented at ISASI 2010—Sapporo, Japan

Opening Address—*Frank Del Gandio, President, ISASI*

Keynote Address: A Japan Transport Safety Board Air Safety View—*Norihiro Goto, Chairman, JTSB*

TUESDAY, SEPTEMBER 7

Authentic Investigations

How Can We Have an Authentic Investigation?
By Guo Fu, Deputy Director, Aviation Safety Office, East China Regional Administration, Civil Aviation Administration, China

A Quarter Century and Still Learning—Lessons from the JAL123 Accident Investigation
By John Purvis and Ron Schleede, Former Directors of Accident Investigation at Boeing and NTSB.

Asia—Trends and Issues

Leading 'Just Culture' Toward Pragmatic Application in Japan
By Hiromitsu Mizutani, Japan Aircraft Pilot Association, ANA Corporate Safety Captain

Accident Trends in Asia: Major Improvements and Remaining Challenges
By Robert Matthews, Senior Analyst, Accident Investigation and Prevention, FAA

WEDNESDAY, SEPTEMBER 8

Innovative Uses of Data and Intellectual Models

AAIB's Use of Data Mining in the Investigation of the 777 Fuel-Icing Accident: Innovative Outcomes and Challenges Faced
By Mark Ford, Senior Inspector of Air Accidents, AAIB UK

The Contribution of Safety Reporting and Investigations to Safety Management Systems
By Paul E. Mayes, Investigation and Analysis, Safety Risk and Environment, Cobham Aviation Services, Australia

Applying Intellectual Models

Limitations of 'Swiss Cheese' Models and the Need for a Systems Approach
By John Stoop, Delft University of Technology, and Sidney Decker, Lund University

Was It Really Pilot Error? A Case Study of an Indian Military Helicopter Accident
By Capt. Samir Kohli, Head of Safety, Saudi Aviation Flight Academy

Preparing for Investigation

Planning for Sea Search and Recovery Operations—A Small Investigation Agency Perspective
By the Air Accident Investigation Bureau of Singapore

Hazards at Aircraft Accident Sites: Training Investigators in Line with the ICAO Circular 315 Guidelines
By Nathalie Boston, Safety and Accident Investigation Centre, Cranfield University, Graham Braithwaite, Cranfield University, and Sid Hawkins, AAIB

Mental Health Aspects of Aircraft Accident Investigation: Protecting the Investigator
By Brian Dyer, Nevis Disaster Management Department, and Anthony Brickhouse, Assistant Professor of Aviation Safety, Embry Riddle Aeronautical University

Investigating Accidents Related to Errors of Aeronautical Decision-Making in Flight Operations
By Wen-Chin Li, Head of the Graduate School of Psychology, National Defense University, Taiwan; Don Harris, Managing Director of HFI Solutions Ltd., United Kingdom; Lun-Wen Li, Industrial Engineering and Engineering Management, Tsing Hua University, Taiwan; Yueh-Ling Hsu, Professor in the Department of Air Transportation, Kainan University, Taiwan; and Thomas Wang, Acting Managing Director and the Head of the Flight Safety Division, Aviation Safety Council, Taiwan

THURSDAY, SEPTEMBER 9

Investigative Tools and Lessons

The Use of Commercial Satellite Imagery in Aircraft Accident Investigation: Results from Recent Trials
By Matthew Greaves and Graham Braithwaite, Safety and Accident Investigation Centre, Cranfield University

Close Cooperation in Investigations has Improved Technical Partnership
By Michael Guan, Director of the Investigation Lab, Aviation Safety Council, Taiwan, and Christophe Menez, Head of the Engineering Department, Bureau d`Enquêtes et d`Analyses, France (Recipients of the Award of Excellence for Best Seminar Paper)

Terrain Profile Analysis Using Radar Altimeter Data from FDR
By Frederico Moreira Machado and Umberto Irgang, Embraer Air Safety Department

Useful Human Factors Investigative Techniques: A Case Study of a Fatal King Air Accident in Canada
By David Ross, Operations Investigator, TSB, Canada

Effects of Mental Stressors During Flight on Prosodic Features of Speech and Autonomic Nervous Response
By Hiroto Kikuchi, Japan Air Self Defense Force

Recent Accidents: Lessons, Techniques, and Challenges Heathrow 777: Challenges in Understanding Unusual Properties in Aviation Fuel and Problems in Conducting Tests to Determine the Vulnerability of an Aircraft's Fuel System to the Accumulation and Release of Ice
By Brian McDermid, Air Accident Investigation Bureau, United Kingdom

Undersea Search Operations: Lessons and Recommendations from Flight 447
By Alain Bouillard, Head of Safety Investigations, and Olivier Ferrante, Head of Recovery Group, BEA, France

Colgan Flight 3407: Achieving the Delicate Balance Between Timely and Thorough While Staying True To the Investigative Process
By Lorenda Ward, Accident Investigator, NTSB, USA

The following papers were presented, but no text was available for publication.

A Review of Aviation Recorder Development and Challenges in China
By Yang Lin, Senior Engineer for Aviation Recorders, Civil Aviation Safety Technical Center, CAAC China;

Social-Technical Systems and Proactive Accident Prevention
By Yu-Hsing Huang, Assistant Professor, National Pintung University of Science and Technology, Taiwan;

Boeing Airways 777 Accident Investigation: What We Don't Know About Ice and Jet Fuel
By Mark H. Smith, Air Safety Investigations, Boeing Commercial Airplanes

Garver (president), Gaston Gaber (vice-president), De Paul Sunny (secretary/treasurer), and Maggie Wong (public relations), an ISASI 2010 “Kapustin” scholar

A major accomplishment of the Chapter occurred when the officers planned, initiated, and successfully completed a student petition to establish an aircraft accident investigation lab (crash lab) on campus. With more than 300 student signatures and the support of faculty members, the university approved the petition and established the crash lab that the students had wanted. The crash lab is currently used by the students enrolled in the aviation safety courses to enhance their hands-on learning experience. The lab is also used for professional courses affiliated with ERAU’s Center for Aerospace Safety/Security Education.

In Memoriam

Col. Regev Baruch (MO3718), Rechovot, Israel, 2010
Harry H. Black (LC0096), Annandale, Virginia, USA, 2010
Alexander A. Lanoway (LC0109), Punta Gorda, Florida, USA, Jan. 20, 2011
Christian H. Schuberdt (MO4225), Braunschweig, Germany, Dec. 23, 2010
John L. Sheehan (AO3618), Vale, Oregon, USA. Sept. 10, 2010
Lt. Col. (Ret.) Patrick “Pat” J. Ash (AO4621) Anchorage, Alaska, USA, Feb. 16, 2011 ◆

MOVING?
Please Let Us Know

Member Number________________

Fax this form to 1-703-430-4970 or mail to
ISASI, Park Center
107 E. Holly Avenue, Suite 11
Sterling, VA USA 20164-5405

Old Address (or attach label)

Name ________________
Address ________________
City ________________
State/Prov. ________________
Zip ________________
Country ________________

New Address*

Name ________________
Address ________________
City ________________
State/Prov. ________________
Zip ________________
Country ________________
E-mail ________________

*Do not forget to change employment and e-mail address.

Over the past 2 academic years, the student Chapter has also hosted numerous guest speakers who are industry professionals from companies, organizations, and agencies such as Delta Air lines, Southwest Airlines, the FAA, L-3 Communications, JetBlue Airways, and other consulting companies. Besides the prominent guest speakers, student members also had the opportunity to tour the facility at Piper Aircraft, Inc., in Vero Beach, Fla., where they were able to experience and learn more about the aircraft manufacturing process.

Student members stay active in the international Society by attending annual and regional conferences, including the 2009 ISASI Seminar in Orlando, the 2010 ISASI Seminar in Sapporo, and most recently the Southeast Regional Chapter Workshop in Key West. The students continue to promote aviation safety among aspiring aviation professionals at Embry-Riddle Aeronautical University and look forward to meeting more professionals at future ISASI events. ◆

Braithwaite Speaks at CHC Safety Summit

Graham Braithwaite, director of the Cranfield Safety and Accident Investigation Centre, and ISASI’s Investigators Training and Education Working Group chairman, served as a keynote debate speaker at the CHC Safety and Quality Summit, which was promoted as the world’s largest aviation safety conference, in Vancouver.

He participated in the keynote debate with Tony Kern and John Nance, which was facilitated by Scott Shappell, that covered questions ranging from “Has SMS become just another three-letter word?” to “In times of economic hardship, should organizations be investing in safety?” The keynote debate lasted for 90 minutes and was delivered in front of the 675 attendees as a presidential-style debate.

During the afternoon, Graham gave a few sessions aimed at CEO/SVP level attendees who worked for a range of fixed- and rotary-wing operators, oil and gas producers, insurers, regulators, etc. Graham discussed the importance of investigation to the smooth running of a safety management system and the role that senior managers play in ensuring that investigators are suitably trained, resourced, and empowered in the role. The importance of an organization’s culture regarding a successful investigation and the effect of a successful investigation in defining an organization’s culture were discussed. The final session was a workshop on accident investigation, which attracted more than 125 participants ranging from small operators to national investigation agencies.

In accepting the invitation to speak, Braithwaite said, “I am absolutely delighted to be a part of what I consider to be such a world leading event. The CHC Safety and Quality Summit has established itself as the gold standard for applied safety management within the rotary and fixed-wing sector of the air transport industry. CHC’s inspirational leadership in safety is always clearly demonstrated by the speakers and attendees of this event—professionals from all over the world who come to

NEW MEMBERS

Individual

Abdulhamid Belama, Salah, Maydan Elzazayer, Libyan
Acosta-Martinez, Leo, G., Daytona Beach, FL, USA
Adamson, Keenon, Los Angeles, USA
Alencar, P. Allan, Sugar Land, TX, USA
Branham, Brittnee, N., Daytona Beach, FL, USA
Cabrera, Ricardo, C., Miami Springs, FL, USA
Chan, Anthony, G., Prescott, AZ, USA
Flóvenz, Gunnar, J.Ó., 110 Reykjavik, Iceland
Garver, Michael, Gulf Breeze, FL, USA
Gee, Clifton, E., Hagerstown, MD, USA
Herl, Cody, J., Daytona Beach, FL, USA
Hewitson, Robert, L., Seacliff, SA, Australia
Ibarra, Adolfo, Prescott, AZ, USA
Iyengar, Nitish, P., Saint Augustine, FL, USA
Jenkins, Kenneth, D., Dallas, TX, USA
Little, Emma, L., Conder, ACT, Australia
Masters, Greg, F., Daytona Beach, FL, USA
Moore, Wiley, L., Tacoma, WA, USA
Oliveira, Ivan, Vitória, Espírito Santo, Brazil
Phillips, Jonathan, C., Blackwall, TAS, Australia
Robinson, Christopher, G., Holly Hill, FL, USA
Robson, Ainsley, M., Levittown, PA, USA
Salas Montilla, Ricardo, J., Sugar Land, TX, USA
Shea, William, Hurst, TX, USA
Sizemore, Gary, R., Coatesville, PA, USA
Smith, Kimberly, L., Daytona Beach, FL, USA
Sumner, Thomas, L., Wahroonga, NSW, Australia
White, James, M., St. Charles, MO, USA
Zhao, Karen, Daytona Beach, FL, USA
Ziehm, Robert, Las Vegas, NV, USA ◆

learn from each other and share their own experiences."

Now in its seventh consecutive year, the Summit is an internationally recognized, non-profit aviation safety conference aimed at improving safety in aviation globally through excellence in human factors. The Summit is hosted by CHC Helicopter, one of the world's largest providers of civilian search and rescue services and transportation for the global offshore oil gas industry. CHC has more than 250 aircraft operating in some 30 countries worldwide. ◆

SCSI Appoints New Investigation Director

ISASI corporate member the Southern California Safety Institute (SCSI) has appointed William Fowler as the company's new investigation program director. He brings an extensive background in aviation safety and investigations to SCSI's programs, including experience as investigator-in-charge (IIC) of the MK Airlines B-747 crash in Halifax and as one of the lead investigators of the Swissair Flight 111 crash over Nova Scotia. Stephen Milam, chairman of the Board of Directors, said, "Bill has an incredible depth and breadth of experience from which to draw, and his keen insights stem from a truly unique background rich with expertise in investigation, safety, and human factors. Combine this with his regulatory background, leadership positions, industry knowledge, and level of professionalism and you have a learning opportunity that is second to none."

Prior to joining SCSI, Fowler's most recent appointment was with Transport Canada Aircraft Services Directorate as the Atlantic region manager of flight operations, responsible for the safe operation of multiple fixed and rotary wing aircraft. Prior to this, he was the Atlantic regional manager for the Transportation Safety Board, where he was responsible for all of the regional investigations. It was during this period that he was extensively involved in the Swissair Flight 111 accident, which tragically took the lives of all 229 people on board just eight kilometers from the shore of Nova Scotia. Also during this time, he was the IIC of the MK Airlines B-747 crash in Halifax. His leadership as IIC ensured that the lessons learned from the accident would benefit global aviation.

He also has extensive regulatory experience with Transport Canada. He has held positions as the chief of airline inspection (responsible for the major airlines in Canada) and as chief of foreign inspection (responsible for the certification of foreign carriers operating into Canada). At Transport Canada, his responsibilities also included the Atlantic region flight operations management, training, certification, and proficiency of crews as well as operations management of the regional Canadian Coast Guard helicopter and fleet crews.

Fowler is teaching the SCSI investigation in safety management systems and aircraft accident investigation courses and will be co-teaching several other courses with the company. He will also actively be reviewing and upgrading the curriculum in the entire Investigation Certificate Program. When asked about his transition to program director, Bill said, "With every class, I truly enjoy meeting these outstanding professionals and sharing my experiences and knowledge with them as we work toward our ultimate goal of making aviation safer worldwide."

In other SCSI news is the announcement that SCSI and Global Aerospace Logistics, LLC (GAL) have teamed up to jointly pursue business opportunities within the United Arab Emirates (UAE) in connection with aviation-related safety education and safety management system development. Under their agreement, SCSI will work with GAL to provide proven, comprehensive training solutions and address the immediate safety education requirements for the UAE's armed forces, as well as the UAE civil sector. The initial primary focus is to meet immediate requirements of the UAE armed forces and subsequently to market the highly respected SCSI line of products. ◆

NTSB to Revamp Its Most Wanted List Process

The NTSB has announced plans to modernize it decades-old safety recommendations program. Board members voted unanimously to change its Most Wanted List Safety Recommendations Program Board Order. The Board Order is an internal document that provides policy guidance and establishes procedures for identifying, developing, selecting, and implementing safety recommendations on the NTSB's Most Wanted List.

"With this week's vote, the NTSB will begin a significant transformation of one of our flagship programs, the

Most Wanted List," said NTSB Chairman Deborah A.P. Hersman. "For the past 20 years, the Most Wanted List has spotlighted certain critical transportation safety issues and the NTSB's safety recommendations that would address them. It has been one of the NTSB's most effective tools; but after 20 years, it is in need of a face lift and procedural streamlining. The Board has now paved the way for those important updates to take place.

"The beauty of this new process is the fact that the Most Wanted List can be changed completely each and every year, if the Board so chooses," Hersman said. "This will go a long way to keeping the Moat Wanted List fresh, dynamic, and current for the next 20 years of its life." ◆

President's View, *continued from page 4*

enforcement by national and international aviation authorities, and by pursuit of claims through civil justice systems to obtain compensation.

4 Urge states to safeguard the safety investigation report and probable cause/contributing factor conclusions from premature disclosure and use directly in civil or criminal proceedings. Although use of official accident reports may save criminal investigators the considerable expense of conducting an entire separate investigation, a considerable and serious risk exists of diverting these reports from their original purpose, as technical causes often cannot be equated to legal causes necessary when establishing either civil or criminal liability. In addition, use of relatively untrained and inexperienced technical 'experts' by prosecutorial or judicial authorities, as compared to official accident investigating authorities, can result in flawed technical analyses and a miscarriage of justice, while interfering with the official accident investigation.

5 Urge national aviation and accident investigating authorities to: (i) assert strong control over accident investigations, free from undue interference from law enforcement authorities; (ii) invite international cooperation in the accident investigation under Annex 13; (iii) conduct professional investigations to identify probable cause and contributing factors and develop recommendations in a deliberative manner, avoiding any 'rush to judgment'; (iv) ensure the free and voluntary flow of essential safety information; (v) provide victims' loved ones and their families with full, accurate, and precise information at the earliest possible time; and (vi) address swiftly any acts or omissions in violation of aviation standards." ◆

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

Who's Who, *continued from page 32*

to Microsoft PowerPoint presentations, Excel spreadsheets, and Adobe PDF documents. Interactive dashboards allow users to interact with their data and perform investigations into trends. Built-in modern visualization tools include interactive graphs, cockpit displays, and Google maps. A built-in technical support function is also available.

For air safety investigators, the value of POLARIS lies in its simplicity of use, cost effectiveness, and accessibility—whether the user is in the office or working in the field.

FDS is initiating an online POLARIS community to further facilitate and promote knowledge sharing within the industry. Air safety professionals are invited and encouraged to contribute. A place for like-minded professionals to provide input, the POLARIS community ensures that contributions will be made accessible to the aviation safety world.

ISASI membership promises to be very beneficial to Flight Data Services in building a community relationship with flight safety specialists to develop best practices for sharing flight data analysis algorithms and lessons learned from past investigations. ◆

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WHO'S WHO

Flight Data Services: Offering Complete Flight Data Management

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

Flight Data Services (FDS), from its head office in the UK, offers a complete flight data management service to the commercial aviation industry. As a global leader in flight safety innovation, FDS recently delivered the first major advancement in flight data monitoring (FDM) for the decade—a flight data analysis tool designed specifically for the Internet.

Since opening its doors for business in 2000, FDS has delivered tailored monitoring services to its global customers, setting up a U.S. business division in 2007 to support Flight Operations Quality Assurance (FOQA) requirements. Today, FDS monitors more than 800 aircraft worldwide. With well more than a million flights in its data archive, collected from more than 70 aircraft types, FDS is unique in providing benchmarking statistics across its customer base, benefiting both small and large fleet operators.

FDS also offers a consultancy service, designed to assist airlines in carrying out flight safety activities, providing everything from a simple gap audit to setting up a complete safety department.

With a premium, complete, and dedicated service that is accessible 24/7, FDS maintains the highest ratio of analysts per aircraft in the industry. The customer friendly analyst team includes professionals from many sectors of the industry—flight crew, navigation, engineering, dispatch, and air traffic control—offering specialized expertise and a full range of quality services.

Operators can choose from a full-service program that includes data transfer, data processing, and data validation or a hosted service, which is an ideal platform for operators that wish to maintain ownership of the data validation process.

The innovative Internet-based POLARIS program is an integrated, open-source solution that can be accessed from anywhere an Internet connection is available. There is no proprietary hardware or software to purchase, learn, or maintain. POLARIS is a zero-footprint, cross platform solution that allows users to browse, investigate, and use statistics immediately upon set up.

Statistical reports can be exported

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