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"Air Safety Through Investigation"

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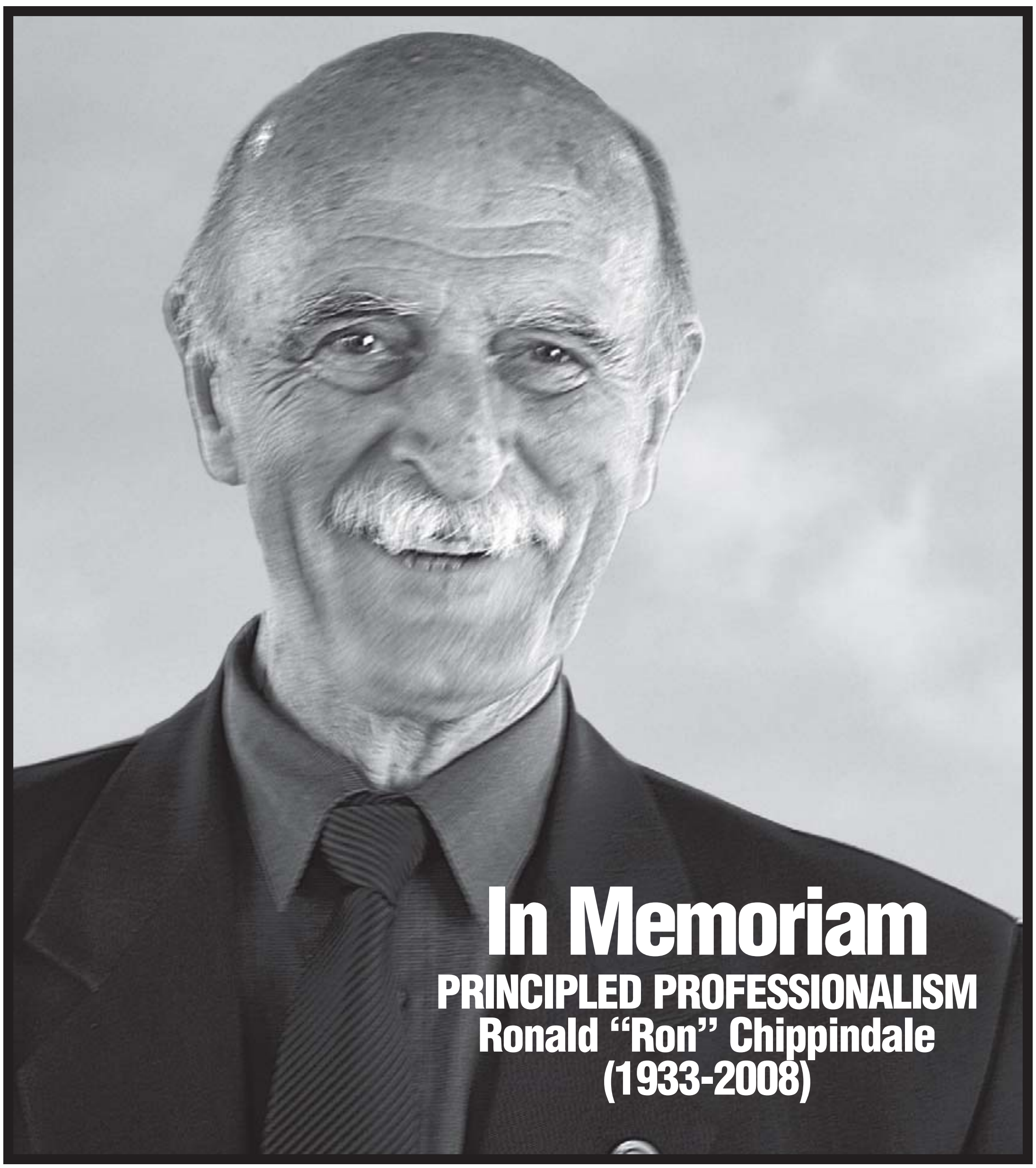

In Memoriam

PRINCIPLED PROFESSIONALISM

Ronald "Ron" Chippindale

(1933-2008)

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"Air Safety Through Investigation"

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AIR SAFETY INVESTIGATORS
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Ron Chippindale 'Flies West'

By Frank Del Gandio, ISASI President

"To fly west, my friend, is a flight we all must take for a final check."—*Author unknown*

On February 12 at 7:25 a.m., one of ISASI's staunchest advocates began his "flight west." Ronald "Ron" Chippindale was doing his daily early morning walk along a footpath near his home in the Aotea subdivision of Porirua, Wellington, New Zealand, when an 18-year-old driver lost control of his car and struck Ron. He died instantaneously.

Ron joined our Society in 1971 and his involvement in ISASI was nothing short of phenomenal. He was instrumental in forming the New Zealand Society and became its first president, serving in that post until 2004. He was the NZSASI councillor up to his death. Ron attended every scheduled International Council meeting and was very involved and instrumental in the Council's policy-setting role. He met his representation responsibilities with zealous constructive participation in debating issues and ensuring alternative options were considered. Ron chaired the Organizing Committee for the 1986 ISASI seminar that was successfully held in Rotorua, New Zealand, and again in Auckland in 1996. In 1993, he became one of the first to attain ISASI Fellow status. In 2002, he was granted "Life" membership. In 2004, he was presented with ISASI's highest honor, the Jerome F. Lederer Award, for his outstanding lifetime contribution in the field of aircraft investigation and prevention, which is outlined below.

Ron gained international attention and respect in 1979 as the investigator-in-charge of the investigation into the tragic Air New Zealand DC-10 accident in which 257 persons died when the aircraft descended into an ice field near Mt. Erebus in Antarctica. His work on the case has been described as nothing short of brilliant.

Ron's acceptance speech exemplified the characteristics of his demeanor and accident investigative manner: short on banter and long on meaningfulness. He said, "I have been in awe of those who have been nominated for the coveted Jerry Lederer Award. To have myself selected for this honor is rather overwhelming." (See ISASI Forum October–December 2004, page 14).

Ron, born in England on March 26, 1933, enlisted in the Royal New Zealand Air Force (RNZAF) in 1950 and was one of the first two RNZAF trainees selected to train with the Royal Air Force at Cranwell in the U.K. When he returned to New Zealand, he brought back his bride, June.

Ron accepts the ISASI 2004 Jerome F. Lederer Award from Frank Del Gandio, ISASI president.

Ron flew Bristol freighters with the No. 41 Squadron and later Hastings and DC-6 aircraft with the No. 40 Squadron. He had operations service during the Malayan Emergency and in Borneo.

He has served in a flight safety officer capacity since 1959, and in 1969 Squadron Leader Chippindale became the New Zealand Defense Headquarters flight safety officer responsible for the air staff policy on flight safety and the investigations of accidents for the Army, Navy, and Air Force. When he retired from the Air Force in 1974, after 24 years of service, he literally moved next door to be an inspector of air accidents with the Office of Air Accidents Investigations, a part of the Ministry of Transport. He became its chief inspector in 1976.

In 1990, the Transport Accident Investigation Commission (TAIC) replaced the Office of Air Accidents Investigations. Ron was the acting chief executive for 2 years as well as the chief investigator of accidents. As the mandate of the Commission expanded to include marine and rail, Ron adopted aviation investigation methodologies for those modes.

Ron led or was involved in the investigations of more than 2,000 aircraft accidents and incidents, which made his name

(Peter Williams, president of NZSASI, and Steven Lund contributed to this memorial.)

Ron's presence will be sorely missed by his family,

synonymous with aircraft accident investigation. He gained international attention and respect in 1979 as the investigator-in-charge of the investigation into the tragic Air New Zealand DC-10 accident in which 257 persons died when the aircraft descended into an ice field near Mt. Erebus in Antarctica. His work on the case has been described as nothing short of brilliant. Many compare the complexity of the investigation to that of the later TWA Flight 800 investigation. With a very small team, he managed an investigation in a very difficult environment, and encountered both political and cultural stresses. His main finding was challenged through a one-man Royal Commission of Inquiry, but the report of the New Zealand Office of Air Accidents Investigations stands as the official report of the accident. Throughout the ensuing controversy about the report's findings, Ron steadfastly expressed himself and stood by his principles on behalf of air safety.

Ron was known by his fellow investigators as being a very dedicated, thorough, and impartial professional—one who did not hesitate to assuredly speak his mind, even in the face of staunch opposition.

Recognizing Ron's skills, ICAO developed a long-standing relationship with him. In 1986, he worked with the ICAO Technical Cooperation Bureau, assisting in the South African investigation where a Mozambique Tu-134 aircraft crashed and the president was killed. In 1993, when the Russian Federation finally made available the fight recorders from the shoot down of KAL Flight 007, a B-747, over the Sakhalin Islands, ICAO assigned him to the team in the reopened investigation. Ron has also been an enthusiastic supporter of the ICAO AIG meetings.

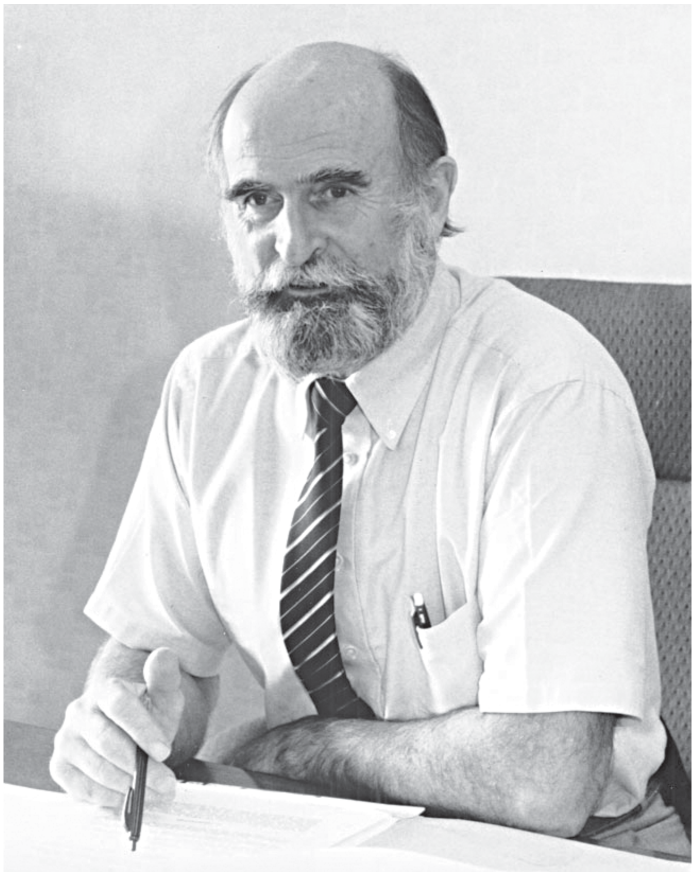
Peers Honor Memory

At press time, three groups within ISASI have honored the memory of Ron Chippindale with donations to the ISASI Rudolph Kapustin Memorial Scholarship Fund in Ron's name. The Fund sponsors the annual scholarships awarded to college students. The sentiments of the contributors are well expressed in this comment from the Pacific Northwest Regional Chapter: "All of us who knew Ron Chippendale—and there are many of us—were deeply saddened by his unexpected and untimely death. We mourn along with Ron's wife June, his family, and his many, many friends."

Units making donations include the Pacific Northwest Regional Chapter—$500, the Canadian Society of International Safety Investigators—$500, the European Society of International Safety Investigators—$500, and the Mid-Atlantic Regional Chapter—$500. At press time, the New Zealand and Australian Societies were determining the nature of their memorial. ◆

Ron (second from right) makes his New Zealand councillor's report to the ISASI International Council at its September 2004 meeting.

friends, ISASI, and the aviation community.



Ron in a 1992 photo at his TAIC chief's desk.

Ron (second from right) is among the five ISASI Fellows present at ISASI 2005. Shown, left to right, are Ron Schleede (2002), Caj Frostell (2003), John Rawson (2005), Ron (2004), and John Purvis (2001).

Following the presentation of the New Zealand Service Medal from Police Minister Annette King (center), Ron accepts congratulations from Police Commissioner Howard Broad. The Medal was presented for his IIC leadership of the accident investigation into the DC-10 that descended into an ice field near Mt. Erebus in Antarctica in 1979.

In 1999, he was an ICAO consultant assisting the secretariat in the conduct of that year's meetings. He served several times as a consultant assisting in various projects, including the development of the ICAO circular on family assistance and enhancement to the ICAO ADREP data system.

Ron was a member of the Returned and Services Association for military veterans and a Fellow of the Royal Aeronautical Society. He was also the recipient of the New Zealand 1990 Commemorative Medal for his services as chief inspector of air accidents and in 2007 received the New Zealand Special Service (Erebus) Medal, awarded to those involved in the Erebus accident recovery and investigation.

Among the 280 people saying a final farewell at his funeral service was the New Zealand minister for Transport Safety and representatives from the Air Force, the aviation industry, and public service. Ron's family members gave moving accounts of a loving father and grandfather. Capt. Tim Burfoot, chief investigator of the Transport Accident Investigation Commission, gave an overview of Ron's accident investigation career. That was followed by eulogies from Paul Mayes, on behalf of ISASI and ASASI, Peter Williams on behalf on NZSASI, and a personal tribute from Milton Wylie, a friend and co-worker of many years. Ron is survived by his wife June, four children, 10 grandchildren, and one great granddaughter. His presence will be sorely missed by his family, friends, ISASI, and the aviation community.

As the last post and reveille were sounded, a formation of three Royal New Zealand Air Force aircraft made a fly past with trailing smoke.

A fitting send off to his "flight west." ◆

Identifying CVR Recorded Sounds

Sound identification and voice recognition are aimed at offering more clues in the analysis and classification of speech and non-speech CVR signals.

By Yang Lin (AO5012), Center of Aviation Safety Technology (CAST) of CAAC, and Wu Anshan and Liu Enxiang, General Administration of Civil Aviation of China (CAAC), Air Safety Office

(This article was adapted, with permission, from the authors' presentation entitled Sound Identification and Speaker Recognition for Aircraft Cockpit Voice Recorder, *presented at the ISASI 2007 seminar held in Singapore, Aug. 27-30, 2007, which carried the theme "International Cooperation: From Investigation Site to ICAO." The full presentation including cited references index is on the ISASI website at www.isasi.org.—Editor)*

Traditionally the flight data recorder (FDR) has played the major role in establishing the causes of most accidents or incidents. However, information contained in the cockpit voice recorder (CVR) is also very useful during such investigations by providing a better understanding of the real situation. The CVR can act effectively as a latent signal transducer for both speech and non-speech audio information. Some typical techniques, such as sound identification and voice recognition, appear to offer significant clues in the analysis and classification of speech and non-speech CVR signals.

The CVR records audio information on four channels. Non-speech information from the cockpit area microphone (CAM) is recorded on Channel 1. CAM records thumps, clicks, and other sounds occurring in the cockpit other than speech. Channel 2 and 3 of the CVR record speech audio information from the captain's and first officer's audio selector panels. Channel 4 records the audio information from the jumpseat/observer's radio panel.

Background cockpit sound identification

While it may be hard to believe that non-speech sounds are highly important to the investigation of aircraft damage, they are because the background cockpit sounds can reveal problem areas of the aircraft during the time leading up to the accident. Non-speech data from the CAM can be analyzed with sound spectrum analysis to detect whirl flutter, as well as possibly distinguish the sound of a bomb explosion from the sound of cabin decompression. Spectrum analysis can also be used to confirm that the clicks and thumps recorded by the CAM are simply generated by cockpit controls and the sound of the aircraft moving through the air.

Analysis background information recorded in aircraft CVRs has been proposed as a complement to the analysis of onboard FDRs in civil aircraft investigations. One reported case provides a good example of the analysis of CVR data playing a key part in an aircraft accident investigation. In 1992, a 19-seater commuter aircraft crashed during an evening training mission. At that time, the U.S. Federal Aviation Agency (FAA) did not require the installation of an FDR on board all small commercial aircrafts, and the CVR on board the small jet that crashed was the only flight record available to provide clues to the causes of the accident.

Fortunately, in this case, the CVR recording not only included the voice communication, but also structural acoustics as well as other sounds and noise sources. This allowed the accident investigation to focus on the non-speech sounds taken from the CVR tape. A close inspection of the time series from the CVR track revealed a periodic set of transient components occurring at a frequency of 0.86 Hz. Comparing this frequency with an independent dynamic analysis of the engine mount damage, the 0.86 Hz transient data were demonstrated by independent structural and flutter analyses to be quite close to the frequency expe-

__Yang Lin__ has more than 12 years' experience in the field of aviation safety and is an ISASI member. Currently she is an air safety investigator (ASI) and senior engineer at the Civil Aviation Safety Technical Center (CASTC) of Civil Aviation of China (CAAC), where she has been working since 1994. While at CASTC, she analyzes and presents recorded data in support of accident/incident investigations and also conducts flight data recorder readouts on behalf of government authorities and airlines in China and other countries.

Photo unavailable

__Wu Anshan__ is a senior ASI with CAAC, having joined the agency in 1970. He investigates the air traffic control and organizational aspects of aviation accidents and incidents and has substantially contributed to more than 20 significant investigations.

Photo unavailable

__Liu Enxiang__ is the deputy director at the CAAC's Office of Aviation Safety. An 18-year veteran of CAAC, he has participated in several national aircraft accident investigations as an investigator-in-charge (IIC) and as an expert in investigation of avionics equipment. He graduated from Nanjing University of Aeronautics and Astronautics with a degree in aeronautical engineering and has commercial aviation aircraft maintenance experience.

and Voices

rienced from a damaged engine mount.

Moreover, there was a sudden, loud sound at the end of the tape. This 25-millisecond-long event was much louder than the sound in the cabin. Although this short length of the sound did not provide adequate audio listening time, there was enough signal time and amplitude to perform wavelet and voice recognition analysis. The conclusion drawn after the investigation was that the engine on the starboard wing separated during the flight. Subsequently, the fallen engine struck the tail of the aircraft, damaging most of the horizontal surfaces. The loss of the engine also led to the separation of the right wing panel outboard of the engine. As a result, the aircraft pitched down, rolled to the right, and crashed.

The results of the accident investigation described above, and that of Pan Am Flight 103, which disintegrated over Lockerbie, Scotland, in 1989 due to a bomb explosion, motivated CASTC to explore the analysis of aircraft CVR sound sources for use in aircraft accident investigations.

In our system, background cockpit sound identification is used to find the audios identical to the given audio in the background cockpit sound database. An audio ID is identified by audio fingerprint in acoustics. An audio fingerprint is composed of a series of audio features. Generally, audio feature design should obey the following guidelines, as noted in J. Haitsma and T. Kalker's "Robust Audio Hashing for Content Identification":

- Discriminability: sensitive enough to distinguish the different audios.
- Robustness: stable enough to various codes, channels, and modest noise.
- Compactness: small enough for easy storage.
- Simplicity: inexpensive to compute and easy to implement.

There are many approaches available to extract audio features. Mel Frequency Cepstral Coefficients (MFCC) are used as audio features in "Robust Sound Modeling for Song Detection in Broadcast Audio," and in "Method and Article of Manufacture for Content-Based Analysis, Storage, Retrieval, and Segmentation of Audio Information." "Content-Based Identification of Audio Material Using mpeg-7 Low-Level Description" takes the spectral flatness measure as feature parameters. C. Papaodysseus takes the choice of band representative vectors, which is an ordered list of indexes of bands with significant energy. In the approaches cited above, the audio signal is segmented into frames first and a set of features are extracted frame by frame. Some approaches compute a block of features from a big segment of audio.

The background cockpit sound feature extraction approach proposed in this article is based on "Robust Audio Hashing for Content Identification." It takes into account that the sign of spectral band energy difference (both in time and frequency axis) is very robust to many kinds of processing. By analyzing this approach carefully, we propose an improved approach, one that enhances the robustness of the audio feature significantly. When audio features are ready, the below outlined Background Cockpit Sound Identification System (BCSIS) will be able to search identical audios in the database quickly and effectively.

J. Haitsma presented a method that locates the potential identical audios by a hash table. It is quite efficient. But it needs about four times or more space to save data compared to other methods, and it slows down the process dramatically when audios are in bad quality.

A. Kimura adopted a two-pass search strategy. He generated the vector codebook of audio features first and obtained the distribution of vector code within a period of audio. This distribution is then compared to that of a given audio. This comparison is regarded as the first rough search. The audios with similar distribution will continue to go in for the next fine match. Since the distribution comparison is processed by a block of frames instead of frame by frame, it can search audios quickly. The beam-based search approach cuts off branches whose cumulative match scores are higher than the beam width from the best score. Plenty of unpromising paths are pruned away during the search process. The search space is reduced dramatically and high efficiency is achieved.

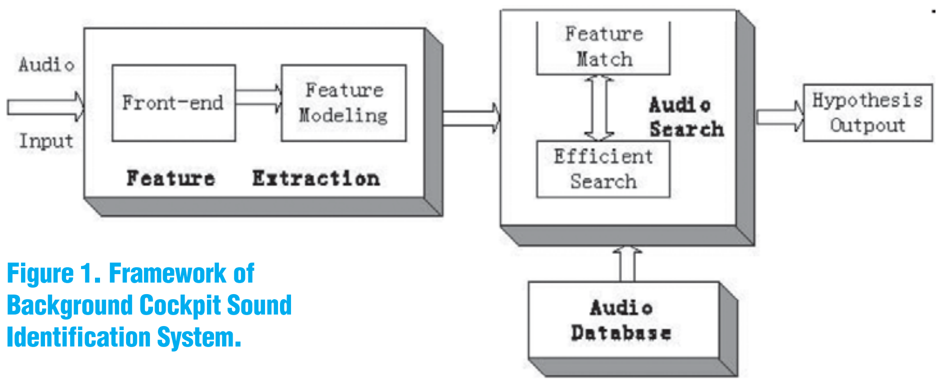


Figure 1. Framework of Background Cockpit Sound Identification System.

Framework of Background Cockpit Sound Identification System

Figure 1 shows the framework of the System. It is composed of three modules: feature extraction, audio search, and audio database. When audio signals are fed into the System, it extracts audio features first. Audio features are compared to the features in the audio database. Audio candidates are generated according to the result of the match process.

The feature extraction module does

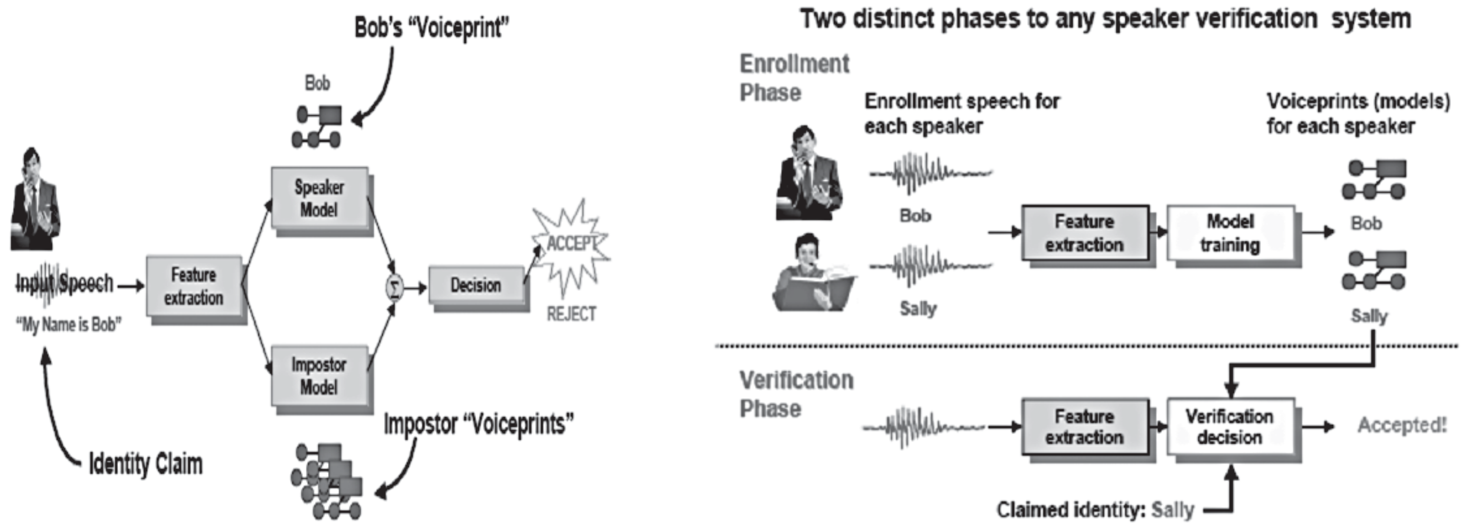


Figure 3. Speaker Identification and Speaker Verification System.

some preliminary processing, such as down sampling and low band pass filtering. Then it computes the audio features using the algorithm described below. The audio feature database stores the audio features computed in advance. The audio search module compares the features of possible identical audios and outputs the best candidates.

Audio feature extraction approach —Figure 2 shows the audio feature extraction flow chart adopted. Because human hearing is most sensitive to the frequencies below 2,000 Hz, high-frequency parts lose heavily when audios are encoded at very low bit rates. Accordingly, in this System audio signals are down sampled to 5,000 Hz first. Then signals are segmented into frames and weighted by a hamming window. Fourier transformation is performed, and spectrum power is obtained. A total of 33 overlapped frequency bands are used at an equal logarithm interval. A 32-bit audio feature is computed for each frame.

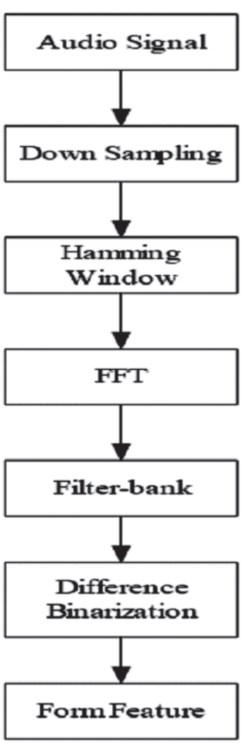


Figure 2. Feature extraction flow chart.

In order to make the audio feature stable, a frame length as long as 410 milliseconds is chosen. Frame shift is only 12.8 milliseconds. As a result, the frame boundaries of audio queries in the worst case are 6.4 milliseconds off from the boundaries used in the database that are precomputed.

Audio search approach—In the audio feature similarity measurement, each frame has one 32-bit audio feature. The similarity of two features is measured by the Hanning distance, which is the number of different bits. The smaller the Hanning distance, the more similar the two features are and vice versa. Bit error rate (BER) defines the similarity of two audio feature serials with the same length. Let **X**, **Y** are two audio feature serials, $\mathbf{X}=\{x_1, x_2,\ldots, x_N\}$, $\mathbf{Y}=\{y_1, y_2,\ldots, y_N\}$. Where N is the frame number of the features. The BER between **X** and **Y** is

$$BER(X,Y) = \frac{\sum_{i=1}^{N} H(x_i, y_i)}{32N}$$

Where, ***H***(.) is the Hanning distance between **X** and **Y.** Obviously, ≤BERd≤, the lower the BER is, the more similar the two feature serials are.

Beam-based search approach—When searching audio candidates in the audio database, it would result in very low efficiency if a whole match comparison is processed at every possible starting frame. A beam-based search strategy is presented in this System to avoid low efficiency. The main idea of this approach is that it takes the current best score as the base and prunes away all branches whose scores are higher than the base plus the empirical threshold (beam width).

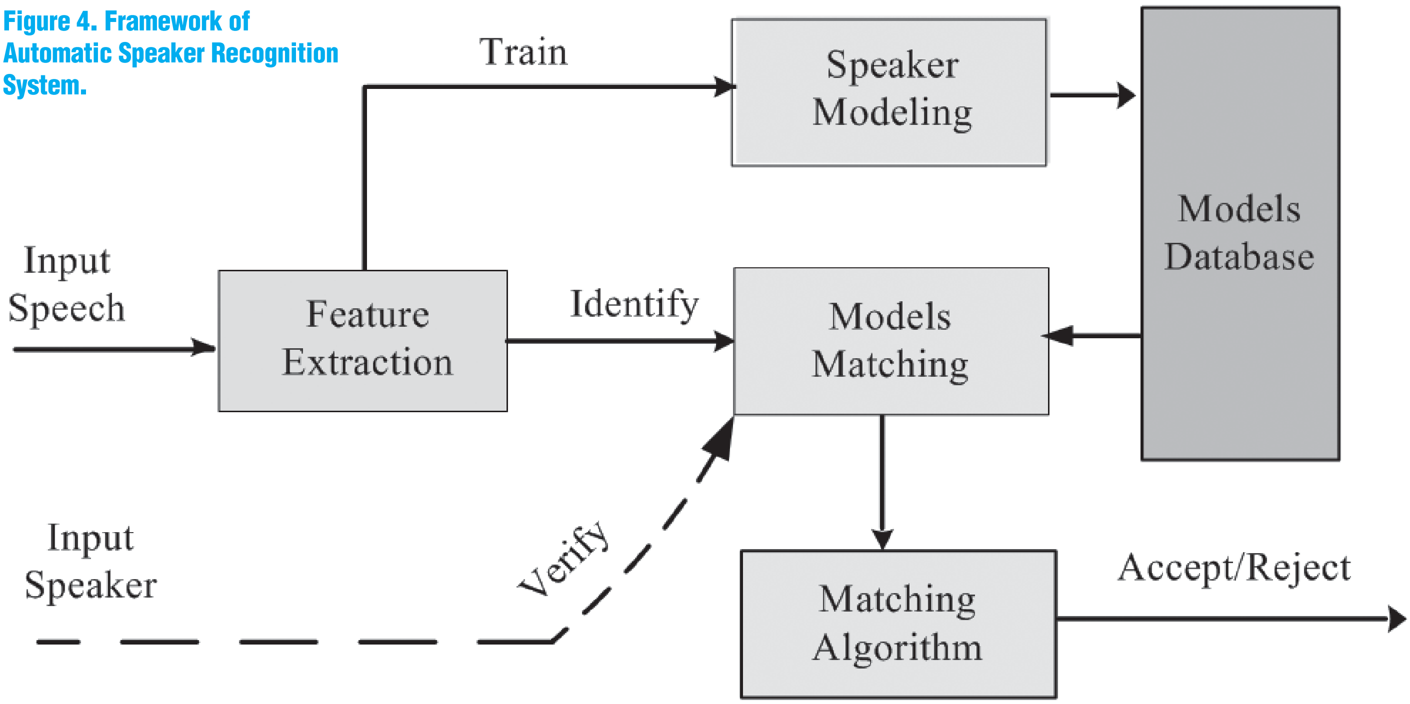
Automatic speaker recognition

Automatic speaker recognition automatically extracts information transmitted in the speech signal, which can be classified into identification and verification, and identifies a speaker based on his or her voice in the CVR recording. Speaker identification is the process of determining which registered speaker provides a given utterance. Speaker verification is the process of accepting or rejecting the identity claim of a speaker. Speaker recognition methods can also be divided into text-dependent and text-independent methods. The former requires the speaker to say key words or sentences having the same text for both training and recognition trials, whereas the latter does not rely on a specific text being spoken (Figure 3).

Current state-of-the-art systems for text-independent speaker recognition use features extracted from very short time segments of speech and model spectral information using Gaussian Mixture Models (GMM). Using a Universal Background Model (UBM)/GMM-based system is now compulsory to obtain good performance in evaluation campaigns such as the U.S. National Institute of Standards & Technology (NIST) Speaker Recognition Evaluation (SRE).

NIST has conducted an annual evaluation of speaker verification technology since 1995. Such an approach, while successful in matched acoustic conditions, suffers significant performance degradation in the presence of ambient noise. Some

Figure 4. Framework of Automatic Speaker Recognition System.



methods are proposed to compensate for channel variation and intra-speaker variation by normalization techniques such as the Cepstral Mean Subtraction (CMS), feature warping, feature mapping, and joint factor analysis.

Modeling of spectral information by GMM can be improved or complemented by the use of other modeling techniques like Support Vector Machines (SVMs) or by transformations of the cepstral space. However, short-term cepstral modeling fails to capture longer-range stylistic aspects of a person's speaking behavior, such as lexical, rhythmic, and intonational patterns. Recently, it has been shown that systems based on longer-range stylistic features provide significant complementary information to the conventional system. Another important issue in the statistical approaches to speaker recognition is that of score normalization, which covers aspects such as the scaling of likelihood scores.

There are two main aspects of speaker features. First, the physiologic structure is different for each individual, such as the track length and oral cavity structure, so the short-time spectral is different. Second, the uttered habits are different, such as an accent.

Framework of Automatic Speaker Recognition System

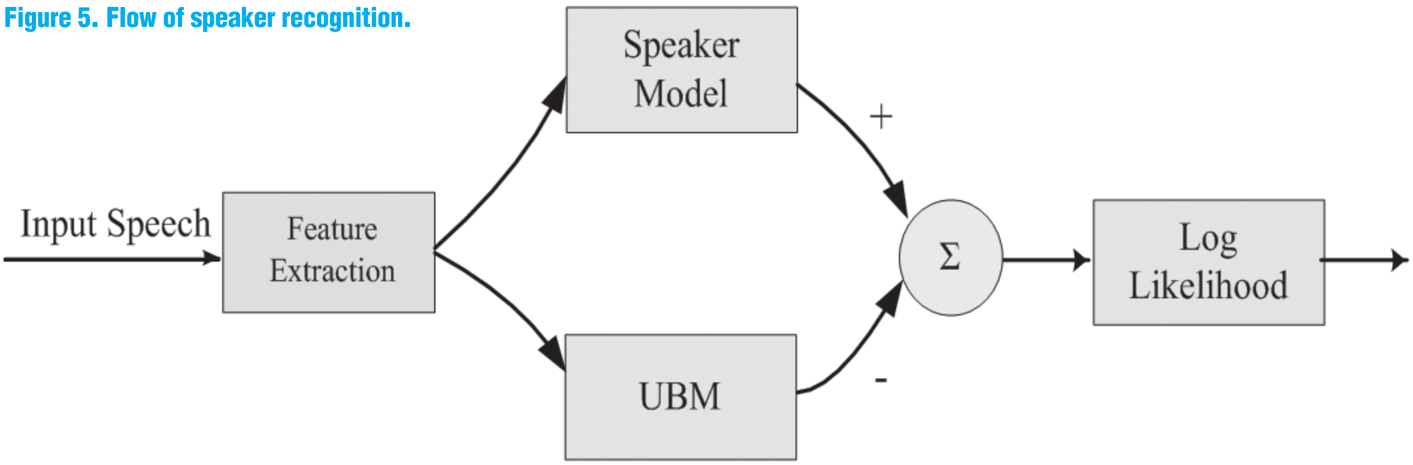
Figure 4 shows the framework of the System. It is composed of three modules: feature extraction, speaker modeling, and speaker recognition. When audio signals are fed into the System, the speaker features are drawn from the input speech segments. Furthermore, the influence of channel and environment is restrained by robust techniques. During the speaker modeling process, input front-end features characterize the speaker. The GMM or SVM modeling approach is used to train the target speaker models, which compose the speaker model database.

Speaker feature extraction approach

The speech signal is smoothed in short time. For analyzing the speech signal, the usual frame concept is introduced by shortening the speech segment by 10 ms-30 ms. The shift length is the half length of one frame. To compensate for the attenuation of the high frequency, every frame of the speech signal uses pre-weighted processing.

There are two main aspects of speaker features. First, the physiologic structure is different for each individual, such as the track length and oral cavity structure, so the short-time spectral is different. Second, the uttered habits are different, such as an accent. It can be described as prosody features. In the field of speech signal processing, the former is

Figure 5. Flow of speaker recognition.



embodied on the structure of frequency. The classical features include cepstral and pitch. And the latter is embodied on the variability of the speech based on the spectral structure. The classical features include the delta cepstral and delta pitch.

In speaker recognition, the cepstral is used mostly and could achieve a good performance. Besides, it can be extracted more easily than other features. At present, the Mel Frequency Cepstral Coefficients are used successfully in speaker recognition, which is proven in applications. In feature extractors of speaker systems, all of the feature vectors are processed by CMS and the feature warping method.

Using the delta cepstral information based on a time domain proves that the performance of speaker recognition is mostly enhanced. In our system, speech data are parameterized every 25 ms with 15 ms overlap between contiguous frames. For each frame, a feature vector with 52 dimensions is calculated: 13 Mel Frequency Perceptual Linear Predictive (MFPLP) coefficients, 13 delta cepstral, 13 double delta cepstral, and 13 triple cepstral.

Two of the speaker models

Cepstral GMM system—The GMM system uses a 100-3800 Hz bandwidth front end consisting of 24 MEL filters to compute 13 cepstral coefficients (C1-C13) with cepstral mean subtraction, and their delta, double delta, and triple-delta coefficients, producing a 52-dimensional feature vector. The feature vectors are modeled by a 2,048-component GMM. The background GMM is trained using data from the NIST 1999 and 2001 speaker recognition evaluation. The features are mean and variance normalized over the utterance. For channel normalization, the feature mapping is applied using gender- and handset-dependent models that are adapted from the background model. Target GMMs are adapted from the background GMM using a Maximum a Posteriori (MAP) algorithm adaptation of the means of the Gaussian components. The resulting scores are T-normed.

Cepstral SVM system—The Cepstral SVM system is based on the cepstral sequence kernel proposed by "The Contribution of Cepstral and Stylistic Features to SRI's 2005 NIST Speaker Recognition Evaluation System." All of them use basic features, which are similar to the cepstral GMM system. The only difference is that MFCC features are appended with only delta and double delta features. This results in a 39-dimensional feature vector. This vector undergoes feature-transformation and mean-variance normalization using the same procedure as explained in the cepstral GMM system. Each normalized feature vector (39 dim) is concatenated with its second (39x39) and third (39x39x39) order polynomial coefficients. Mean and standard deviation of this vector are computed over the conversation side.

Speaker recognition approaches

As mentioned above, the speaker recognition includes speaker verification and speaker identification. The speaker verification is determined by whether the test speech segment is uttered from the given target speaker or not.

The result of recognition is "YES" or "NO," and the comparison happens between one segment and one fixed speaker. The speaker identification is that given the test speech segment.

The system needs to choose the true speaker from the speaker models database. The key function is calculating the log likelihood of the input test speech features and one target speaker model. Its calculated method is denoted as follows:

$$S(X) = \log p(X \mid \lambda_{hyp}) - \log p(X \mid \lambda_{UBM})$$

Where $S(X)$ is the final output score, $p(X \mid \lambda_{hyp})$ is the probability of the speech segment based on the hypothesis model; $p(X \mid \lambda_{UBM})$ is the probability of the speech segment based on UBM. The final output score $S(X)$ is according as the final answer "YES" or "NO" by comparing with the system threshold. The flow of speaker recognition is shown in Figure 5.

The CVR can act effectively as a latent signal transducer for both speech and non-speech audio information. Sound identification and voice recognition are aimed at offering more clues in the analysis and classification of speech and non-speech CVR signals.

From the test we have done, the result shows that two system works quite well for some cases, and the search speed is reasonably fast. ◆

Reverse Engineering Overcomes Corporate Amnesia

A process of "corporate amnesia" has become common among manufacturers, brought about by lengthening aircraft service lives and shortening career spans of design/development engineers within one employer.

By Peter Coombs, Senior Inspector of Accidents, Air Accidents Investigation Branch (AAIB), U.K.

(This article was adapted, with permission, from the author's presentation entitled Use of Reverse Engineering Techniques to Generate Data for Investigations, *presented at the ISASI 2007 seminar held in Singapore, Aug. 27-30, 2007, which carried the theme "International Cooperation: From Investigation Site to ICAO." The full presentation including cited references index is on the ISASI website at www.isasi.org.—Editor)*

Figure 1

Accident investigation has traditionally relied on a variety of sources of evidence. One of the most important has been analytical data supplied by type certificate (TC) holders or original equipment manufacturers (OEMs). Such information is particularly important in those complex investigations involving structural failure. A number of problems with these sources of data have, however, been encountered in recent years.

***Peter Coombs,** an engineering investigator with the U.K. Air Accidents Investigation Branch since 1972, has investigated accidents and incidents to most classes of aircraft including large public transport airliners, transport helicopters, military combat aircraft, and many general aviation types. Before joining the AAIB, he trained with the British Aircraft Corporation. He later served as a design engineer on the Concorde SST. He holds a master's degree in aircraft design and pilot's licenses on single- and multi-engine GA aircraft and on helicopters.*

With mature aircraft types, archived design data in the possession of TC holders may not be readily accessible. If it is available, it may be in a form not easily identified, understood, or manipulated by their structural, aerodynamic, or systems specialists, because they will probably be more used to operating with state-of-the-art design tools. They are often inexperienced in the use of earlier methods of technical analysis and design data recording systems, routinely utilized in the past in the development processes of aircraft and their components. This assumes that the relevant data can actually be located and identified, a situation that cannot always be guaranteed.

A process of "corporate amnesia" has become common among manufacturers, brought about by lengthening aircraft service lives and shortening career spans of design/development engineers within one employer. Some manufacturers seek out long-retired engineering specialists to attend meetings with investigators in often vain attempts to recapture long-forgotten design data. Other manufacturers seem reluctant to part with information they probably possess, either because they find it technically embarrassing in the context of the accident or for reasons about which we can only speculate. The problem seems to be at its greatest when the accident under investigation occurs far from the home territory of the type certificate holders.

The above phenomenon can be unfortunate in circumstances where the compliance of the subject aircraft with the design requirements, or in some respects the adequacy and relevance of those design requirements to the accident circumstances, have come into doubt.

On a number of recent investigations, where structural failures have occurred, a process of "reverse engineering" has been carried out by the AAIB, under the supervision of the author, to combat these difficulties. This has been done in order to establish important parameters that might previously have fallen under the province of the type certificate holder, but where inadequate data have come from that source.

Investigation summaries

The two investigations summarized here have been to aircraft in very different categories, suffering very different accident causes. Similarities in the investigative process for each were, however, considerable.

The first of these events was to a medium-sized, offshore, public-transport helicopter. This suffered a lightning strike resulting in damage to a composite tail rotor blade, which ultimately led to failure of the tail rotor gearbox attachment making continued flight impossible.

Although the gearbox fell from the pylon at the end of the flight, somewhat miraculously the hydraulic pipes did not initially fracture. Instead, they continued to support the mass of the gearbox for a brief period. This preserved the longitudinal balance of the aircraft, enabling a successful autorotation to take place into a rough sea. Shortly afterward, the pipes failed and the gearbox fell away and sank to the sea bed. The aircraft drifted downwind until it also sank. Figure 1 shows the aircraft some time between the loss of the gearbox and the final sinking, shortly after all the passengers and crew evacuated.

The occupants escaped by dingy and were subsequently rescued. Surprisingly, we were successful in recovering both airframe and tail rotor gearbox from two separate locations, both at depths in excess of 700 feet (see Figures 2 and 3).

Figure 2

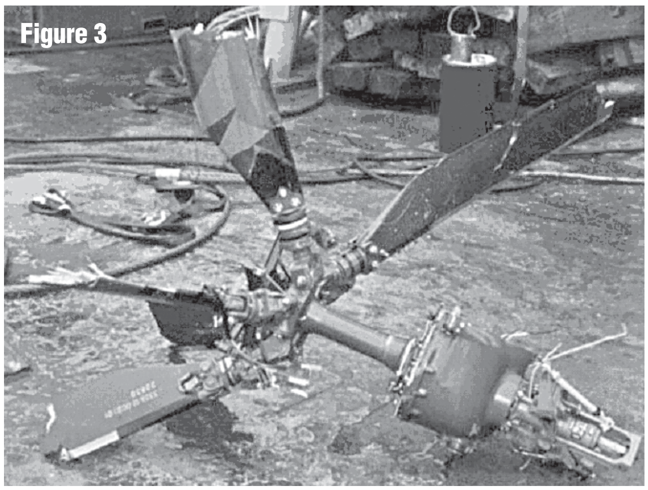


Figure 3

Recordings of the timing and location of the critical lightning strike were obtained using meteorological recording equipment, as was a time-referenced recording of the final radio distress call, made as the aircraft ditched, following the failure of the normal tail rotor gearbox attachment.

The second accident was a fatal event to a four-seat metal general aviation (GA) aircraft, which suffered the unusual phenomenon of a failure of the outboard section of a wing, in a download sense. This occurred while flying in smooth air in daylight visual meteorological conditions. A good quality radar recording and a reliable meteorological after-cast enabled the airspeed history to be calculated with an acceptable degree of accuracy. It was noted with some concern that the speed, at the time of the failure, was significantly below the maneuver speed of the aircraft.

Both investigations resulted in development of methods that could be utilized in whole or more probably in part during future investigations, regardless of the size of aircraft involved. Both investigations required precise assessment of strength and loadings in localized areas of structure.

The first also required assessment of loading applied as a result of tail rotor imbalance acting in conjunction with the dynamic response characteristics of the tail boom and pylon structure of the rotorcraft. These characteristics significantly raised the stress levels in the gearbox attachments resulting from rotor imbalance.

The second investigation, to the GA aircraft, took advantage of state-of-the-art techniques to establish structural strength and aerodynamic loading figures. These were thought to be more accurate than those available to the original aircraft designers.

The expertise required to carry out the detailed calculations in support of these investigations was provided by a number of specialist analytical companies in the U.K. These have generally grown up during the past 25 years. In addition, a U.K.-based, internationally known academic establishment also supplied such assistance. The latter has a wide range of expertise through areas of structural design, flight mechanics, simulation, and dynamic load analysis. The specialist companies provide expertise in areas ranging from finite element analysis to structural dynamics. One has specific experience on maneuver load analysis of fast combat jet aircraft. They act as contract engineers to both major aircraft manufacturers and to other specialist aeronautical engineering companies in Europe and North America.

The accidents

The helicopter, an AS 332, lost part of a composite tail rotor blade as a result of a lightning strike while descending to an offshore rig. Subsequent impact destruction to the remainder of the blade (see Figure 4), as the rotor struck the tail boom during gearbox separation, disguised the amount of initial lightning damage. It can be seen in Figure 5 that four of the blades have been destroyed by this same impact mechanism, although only the one on the left has any evidence of the earlier lightning damage.

It was required to establish the level and degree of initial lightning damage on this single blade in order to determine the severity of the lightning strike that the blade suffered. This was necessary to establish the practical validity of the lightning certification requirements to which the aircraft had been qualified. The loss of the machine had cast considerable doubt on the adequacy of those requirements. It was feared that aircraft operating at low levels, in winter, in the temperate maritime conditions over the North Sea, were especially vulnerable. At the time, this was the busiest area of offshore, long-range, public-transport helicopter operation in the world.

Both investigations resulted in development of methods that could be utilized in whole or more probably in part during future investigations, regardless of the size of aircraft involved.

Tests on a number of ex-service blades were carried out at a lightning test facility to establish the extent of damage inflicted by differing degrees of intensity of lightning strikes.

It was found, from wreckage examination, that imbalance following the strike had created sufficient vibration to cause one of the three gearbox securing bolts to slacken. This both concentrated cyclic bending on only two attachment lugs and altered the natural frequency of the tail boom/gearbox

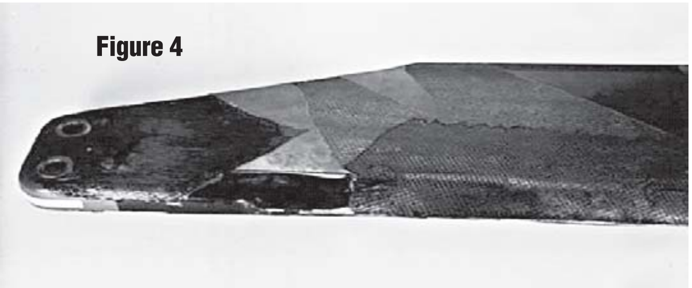


Figure 4

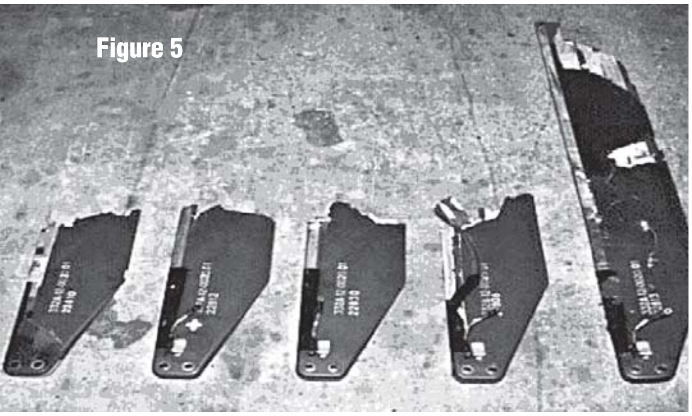


Figure 5

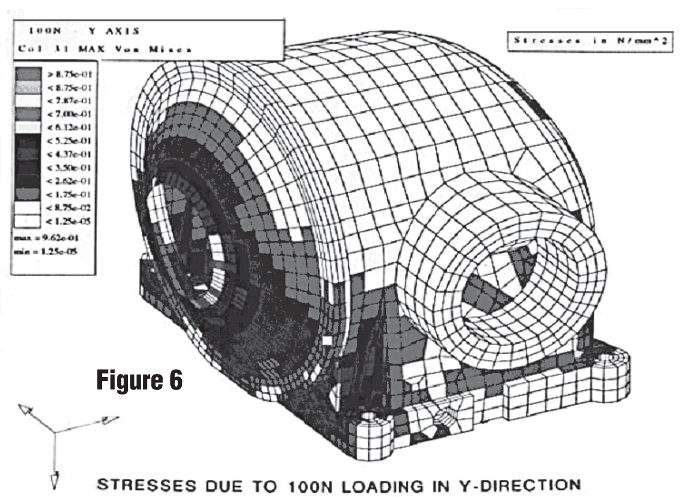


Figure 6

combination. This alteration brought this structural frequency (in cycles per second) close to the rotational speed of the unbalanced rotor with the damaged blade (in revolutions per second).

A finite element analysis of the gearbox was carried out using actual measurements of the casting to create the grid. In Figure 5, you see one of the visualizations of the gearbox showing the varying stress distribution for a unit loading. The number of cycles to failure was known, since the times of both the strike and the final gearbox separation were known from recordings. The initial event time was identified precisely using the atmospheric lightning recording equipment available to the U.K. Met Office, while the failure time was established approximately from timing of the final VHF crew distress call. The rotor speed was known from aircraft data. From these items of information, it was possible to calculate the amount of imbalance that provoked the gearbox fatigue failure and must, therefore, have been brought about by the lightning damage.

When first calculated, however, without considering the dynamics of the tail boom, the mass loss from the blade, to create this imbalance, was found to be slightly more than that resulting from damage clearly caused finally by the collision between the blade and the tail boom. See again Figures 4 and 5. This damage had quite clearly only occurred as the gearbox separated, some minutes after the strike; something was undoubtedly wrong with the calculated result.

It was, therefore, decided that the dynamic characteristics of the tail boom/gearbox combination would be evaluated theoretically. This work was carried out using a manufacturer's dimensioned layout drawing of the tail boom and skin thickness measurements made on the damaged boom by ourselves. The mass of the gearbox was determined simply by weighing the salvaged unit.

The new calculated tail boom dynamic characteristics were confirmed by a resonance test of the rear structure of an in-service aircraft while on the ground and were further corrected theoretically for the predicted effect of a single, loose tail rotor gearbox attachment. By this means, it was determined that the natural frequency of the rear of the aircraft in cycles per second almost matched the rotor speed in revs/second. The cyclic forces applied to the two effective tail rotor gearbox attachments were thus found, as a result of these close frequency similarities, to be far greater than those initially calculated without taking account of the dynamics of the tail boom.

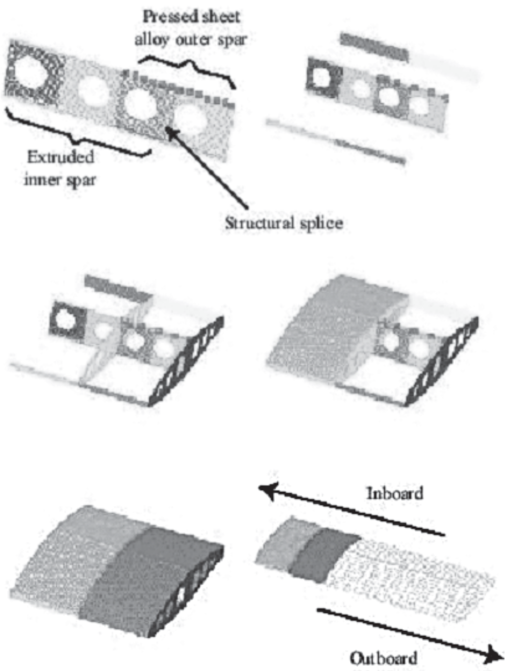
Only a small mass loss resulting from the lightning strike was now required to create loading to cause failure in the known time, and a realistic assessment of the pure lightning damage required to cause this loss could be made. By comparing this calculated mass loss with the damage inflicted by lightning tests on used blades, carried out earlier using known electrical intensity characteristics, it was possible to determine the approximate magnitude of the lightning strike. This, although confirming that the certification requirements then in force were realistic in terms of magnitude for that flight environment, revealed significant drawbacks in the aircraft's design process. It showed that the practical effects of bolt slackening under vibration loading, together with the similarity of natural frequency of the structure to the rotor speed, had not been adequately taken into account at the design stage.

Certification compliance merely called for an absence of severe structural damage in (static) lightning test conditions. It did not call for a full assessment of the structural behavior of the rotor system and mounting after the limited lightning damage had occurred. No such assessment had apparently been carried out on this aircraft type.

Second accident

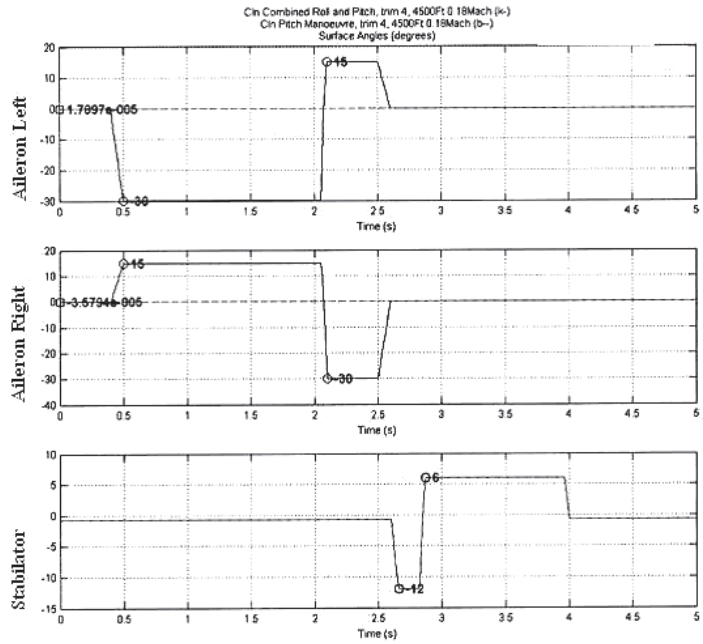
In the case of the GA aircraft, a PA28R-200-2, a finite element (FE) model of the wing bay in which the failure occurred was created using a manufacturer's layout drawing and measurements of panel thickness made on the separated wing and a further sample wing. Figure 7 shows a visualization of the model.

An evaluation of control responses was carried out, using a simple simulator, programmed with a modified NASA computer model of the aircraft type. This was done to produce a realistic series of control column displacement-time histories of pitch control inputs, creating a series of wing download-time (negative G) histories as well as other flight parameters. The span-wise negative lift distribution was calculated and converted to engineering units. The time history resulting in the highest negative load factors achieved in the simulation series was then used to factor the distributed forces. The result was used as the varying aerodynamic force/time input to evaluate the behavior of the FE model under a varying down-load. On carrying out this exercise, it was found that the theoretical wing strength from the FE analysis was far in excess of



Build-up of structural components for Finite Element (FE) model

Figure 7. Finite element analysis visualization.



Control input sequence which resulted in very high wing loads in a downwards direction

Figure 8

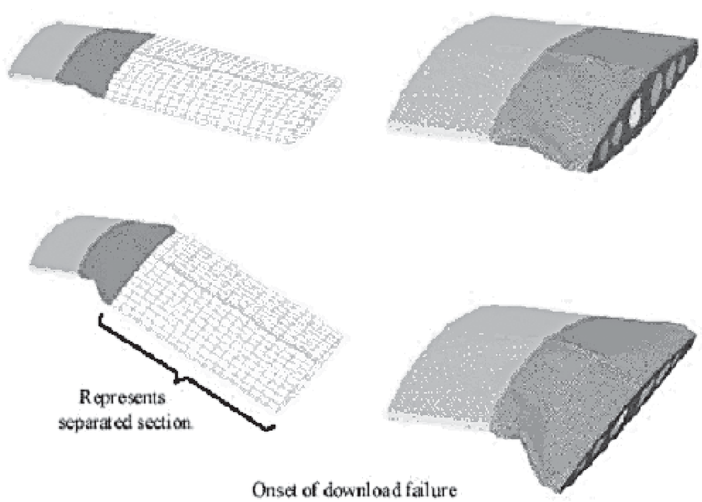


Figure 9. Finite element analysis visualization.

that required to carry the highest loads implied by the results of the simulations.

Up to this point, only symmetrical pitch maneuvers had been considered. It was realized, however, that even with those forces calculated for such maneuvers acting in unison with forces resulting from a large simultaneous roll control input the load to fail the wing could not reasonably be approached, much less achieved. The reason for the wing failure thus remained entirely obscure.

A review of assumptions made to create the finite element model was then carried out; with a number of more pessimistic assumptions applied, the reduction in wing strength was still insignificant.

At this point, further specialist assistance was sought. The company that was consulted drew attention to the significance of inertia effects created by rapidly reversed control inputs. It was able to estimate the approximate mass distribution of the wing structure and also to create a NASTRAN/PATRAN model of the machine, entirely by measurement of a real example and use of published data relating to the type. This enabled maneuver loads to be calculated for continuously varying pitch and roll displacements. It proved possible then to create a maneuver/time history that resulted in failure of the finite element model as a result of full simultaneous pitch and roll control input, followed immediately by complete reversal of control inputs in both axes. Under these influences, failure loads at the wing station where the actual aircraft structure failed could just be reached at the known airspeed. The control input-time histories are shown graphically in Figure 8. Visualizations of the failure modes are shown in Figures 9.

Calculation of control forces at this speed indicated that these were sufficiently low to enable them to be easily generated by a front-seat occupant. (Control gearing was established by simply measuring control surface angular movement for corresponding control wheel travel on an example of the type borrowed for measurement purposes).

A persuasive scenario to explain the occurrence, based on the nature and seating position of the aircraft occupants, in this dual-control machine was then devised.

These two investigations demonstrate the way in which capabilities from partners outside the normal areas of expertise usually called upon by investigators can be harnessed to replace data more usually found from OEMs and TC holders when such data are not readily available. Although the absence of manufacturer's data may seem at first a great handicap, the ever-increasing power of modern computers and the rising sophistication of commercially available analytical packages compensate for much of this loss. These enable data to be generated and manipulated, which produce results that are no less accurate than those achieved in the past by OEMs. These will have used methods that were state-of-the-art at the time of the aircraft's initial design but may be two or more decades old at the time the accident occurs.

Investigations carried out using such methods present a challenge to the manufacturers that frequently reengage more fully when they see that official investigative bodies are serious about finding the root causes of such intricate accidents. ◆

Critical Aspects of International Incident Investigations

The very fine line between incident and accident clearly emphasizes the importance of having well-trained airline investigators.

By Deborah J. Lawrie, Robert N. van Gelder, and Jan Smeitink

(This article was adapted, with permission, from the authors' presentation entitled Critical Aspects of International Incident Investigations, *presented at the ISASI 2007 seminar held in Singapore, Aug. 27-30, 2007, which carried the theme "International Cooperation: From Investigation Site to ICAO." The full presentation including cited references index is on the ISASI website at www.isasi.org.*

The authors are founders of the Independent Safety Investigation & Consultation Services [ISIS] group, part of whose work is to teach others and, especially airline operators, how to investigate serious incidents.—Editor)

This article is based on a case study of a serious deicing incident that had significant consequences for ground handling supervision and developed into a broad-based international investigation, lasting more than 2 years and conducted in accordance with ICAO Annex 13.

On Feb. 16, 2002, a Fokker 70 aircraft had been parked in Turin, Holland, overnight. Rain and snow fell during the night with light and variable winds. The temperature/dew point ranged between 2/0°C and 0/-1°C, and enough fuel remained on board for the return flight to Amsterdam the next day.

During the pre-flight inspection the next morning, ridges of ice 1.5 –2 cm thick were found under the leading edges of the wings, and a mixture of slush and ice was found in small areas on the top of the wings. The aircraft was deiced, and the captain performed a visual check of the wings after the deicing operation was finished. (Kilfrost ABC 3 Type 2/50%).

A short time later, the aircraft taxied for departure from Runway 36. A special pro-

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Robert van Gelder *was born in the Netherlands and received his flight training at the Royal Dutch Flight Academy in 1973. He graduated with a BSc honors from Loughborough University of Technology in human factors/ergonomics in 1982 and joined KLM Royal Dutch Airlines in 1978. He currently flies as a Boeing 747-400 captain. During the last 17 years, Robert has held the positions of ergonomics engineer/human factors specialist, line and simulator instructor, chairman of the Standardization Committee on the Boeing 737, founder and editor-in-chief of KLM's flight safety magazine* in for SAFETY, *and chief investigator.*

Jan Smeitink *is a member of the management team of the Dutch Safety Board, which investigates transport accidents and incidents and other types of disasters, serious accidents and incidents, as well as crisis management and disaster control. He joined KLM shortly after graduating as a mechanical engineer from the polytechnic college in Arnhem, the Netherlands. He flew as a flight engineer on the B-747-200/300 and has more than 10,000 flying hours.*

cedure with a right turn at 500 feet is specified in the case of engine failure during takeoff from this runway due to the close proximity of high terrain. The takeoff was performed using full thrust with the engine anti-ice on. The wind was from the northeast at 3 knots. There were scattered clouds at 500 feet and light rain. The temperature/dew point was 1/0° C.

All the engine indications were normal during the takeoff roll. But during the rotation the fan vibration in engine No. 1 increased, and at liftoff there was a sudden loss of oil pressure and fuel flow to engine No. 2 and the fan vibration in engine No. 1 increased above limits. We now know that as the wings flexed during the rotation, large pieces of clear ice separated from both wings causing violent and immediate destruction of the right engine and damage to several fan blades in the left engine. The following also occurred:

- Accessory gearbox and hydraulic pump housing were cracked.
- Power lever transducer was hanging on its wiring.
- Gear box housing was cracked in two places.
- Throttle linkage was detached from the fan case.

The situation on the flight deck was complicated by the turn that was now necessary at 500 feet, a jammed fuel lever on the right engine, which disrupted the engine shutdown procedure, and several other failures that occurred: an autothrottle failure, an autopressurization failure, and eventually a fuel asymmetry warning.

The high-vibration warning on the left engine was temporarily "hidden" by all the other failures due to the priority allocation of the aircraft's warning system and insufficient space available to display all the warnings at the same time on the Multi-Function Display Unit. Due to all the other failures, the crew remained unaware of the high-vibration problem with the left engine for the next 10 minutes.

When the high-vibration warning eventually surfaced on the Multi-Function Display Unit, the crew then became aware that the only remaining engine was not functioning normally. The first officer later described the situation as "the aircraft was not flying really well and the engine did not feel smooth." The captain declared a MAYDAY and requested vectors to return for an ILS approach on Runway 36 at Turin. After being airborne for 29 minutes, the aircraft finally landed safely back on Runway 36.

The aftermath

[Capt. Lawrie, as chief investigator for KLM, was asked to assist in the incident investigation. She relates her role.—Editor]

By the time I arrived in Turin with the technical pilot, investigation of the incident had already commenced and was under the control of the investigator-in-charge from the ANSV (Italian Aviation Safety Board).

At this stage, it was unclear what had caused the damage to both engines. Other damage to the fuselage and the surface of the right wing led to initial speculation that the damage to the left engine may have been caused by ingestion of debris from the catastrophic failure of the right engine.

As chief investigator for the airline, I had some previous internal incident investigation experience. Quite suddenly now, however, I found myself as the only party on site, in what was to be an international investigation involving several parties and I was dealing directly with the investigator-in-charge. This type of situation is more likely to develop in the case of a serious incident rather than an accident. While the formal procedure calls for an accredited representative under whose supervision the company investigator would act as an advisor, the Turin situation called for an approach that deviated from the ICAO Annex 13 philosophy.

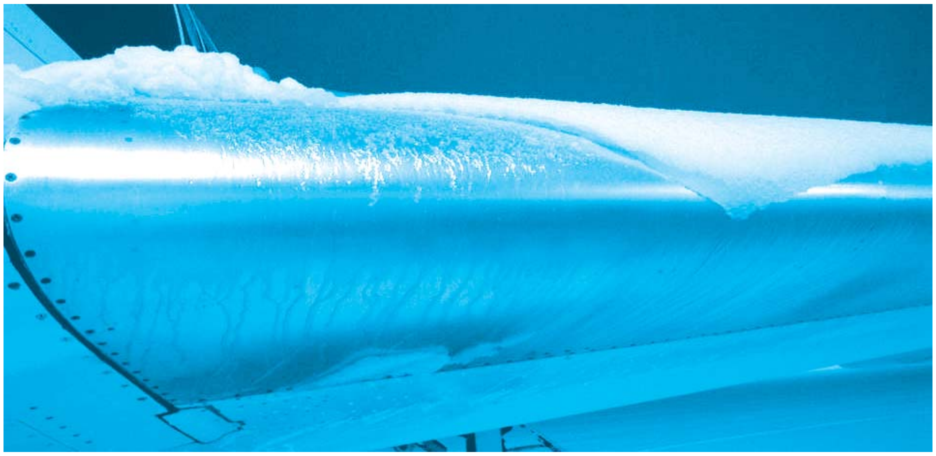
PRECEDING PAGE: This photo illustrates the icing conditions that existed on the evening of Feb. 16, 2002.
ABOVE: Damaged sustained by the Fokker 70's right engine when struck by clear ice from the wing.
RIGHT: This iced wing is illustrative of the problem encountered by the Fokker 70 involved in the noted incident.

In the Turin situation, a comprehensive knowledge and understanding of the ICAO investigation process as well as knowledge about my entitlements and responsibilities and those of the other parties involved was going to prove to be invaluable in what was going to develop into a lengthy and controversial investigation.

The investigator as advisor role

The case study also shows that serious incident investigation is just as important as an accident investigation and, therefore, should be performed as comprehensively and with the same allocation of resources as if it had been an accident. In cases such as Turin where the operator had been fortunate to escape disaster, then investigation of this event had the potential to reveal as much, if not more, about all the contributing factors that led up to it.

Indeed, it was later revealed that the Turin event had the same "footprint" as the Scandinavian Airlines accident that involved



an MD-81 that took off from Stockholm's Arlanda Airport early in the morning of Dec. 27, 1991. Vibrations from the MD-81's engines were noticed 25 seconds after becoming airborne. Approximately 1 minute later, both engines failed. The aircraft was committed to a forced landing in a field where it broke into three parts after the impact. Remarkably, in this accident there were no fatalities, and later the investigation revealed that ice from the wings had entered both engines causing them to fail.

In Turin during the first hours of the investigation, the technical pilot and I worked side by side with the Italian investigator-in-charge (IIC). Our operational knowledge was very much appreciated, and we managed to establish a good relationship with the IIC. Aircraft documents and operating manuals were identified and discussed, a detailed inspection of the cockpit was made, and a brief inspection of the engines and external condition of the aircraft was performed.

The IIC arranged for us to inspect the runway and the surrounding area at the point where the aircraft had rotated. We retrieved pieces of engine acoustic lining among other broken bits and pieces. It was at this critical point in time, however, that the driver of the airport safety car casually mentioned that earlier that morning, just after the incident, he had found some very large pieces of ice at the same location. To close the day, we were invited to accompany the IIC to interview the air traffic controllers who were on duty in the tower at the time of the incident.

I must emphasize that this event did not have the high-profile media attention that one associates with an accident. Also, the seriousness of the event didn't start to filter through to the interested parties until late in the day. The company reported the matter to the Dutch investigation authority, then known as the RVTV. The following day, representatives from Fokker and Rolls-Royce arrived in Turin.

The Italian Aviation Safety Board had initiated the formal international investigation, but our position as advisor to the Dutch accredited representative was not formalized until after we returned to Holland 2 days later. By the time we returned to Holland we had

- established a good working relationship with the IIC.
- met several of the other parties who would be involved in the investigation.
- established our value as advisors in terms of knowledge, expertise, and availability.

An accredited investigator from Dutch ALPA was assigned to me, and together we acted as advisors to the RVTV.

Among the vast quantity of collected data was information from the digital flight data recorder, but information from the cockpit voice recorder was not available due to the jammed fuel lever that had caused the CVR to keep recording for several hours after the incident.

After all the data were collected and extensive analysis of both engines had been performed by Rolls-Royce, the process of elimination led to the conclusion that the most probable cause of the event had been the ingestion of large amounts of ice by both engines. The focus of the investigation turned to the deicing operation, the post deicing inspection, and the operator's supervision of ground handling.

Deicing at European airports was a very controversial and high-profile safety concern at the time, and a few years earlier the DAQCP (Deicing and Quality Control Pool) had been established. The DAQCP was an organized group of operators who shared the auditing of several deicing contractors throughout Europe.

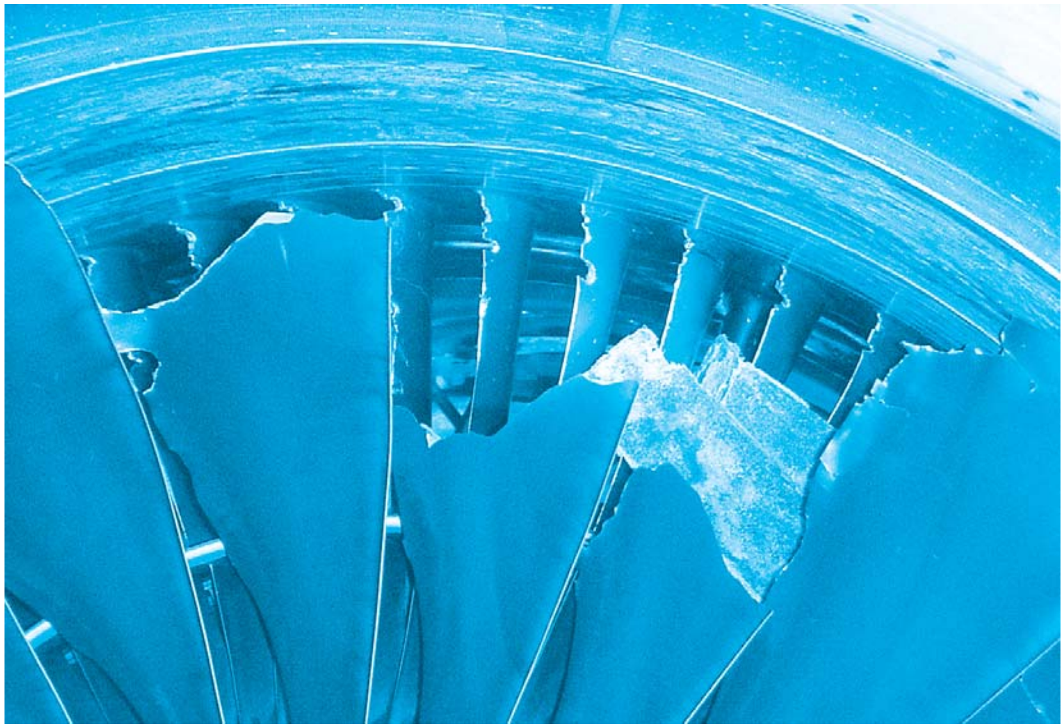
In the Turin investigation, there was controversy over

- knowledge of and training of the correct techniques for the removal of clear ice.
- ownership of the final responsibility for the post-deicing inspection.
- the operator's contractual arrangement with the handling agent that performed the deicing and the agent that performed the inspection.
- the separate arrangement between the handling agent performing the deicing and the agent performing the post-deicing inspection.
- the structural safety deficit at an international regulatory level with no certification rules for ground handling companies.
- evidence of previous substandard deicing operations in Italy.

In the case of Turin, the company had a written contract with a deicing agent but only a verbal contract with the post-deicing inspecting company, which was a separate company to that which performed the deicing.

The crew documentation on board the aircraft indicated that the handling agent would perform the deicing and the post-deicing inspection, but in this case no post-deicing inspection was performed other than the visual check performed by the captain. Furthermore, several findings in relation to training and contracts remained open from the deicing pool audit that had been conducted in January of the previous year.

Tension between investigators was apparent and understandable. Pending insurance claims and political issues also added pressure to the investigation. The importance of the role and the entitlements of the Dutch accredited representative were absolutely vital to the progress of the investigation. In turn, the Dutch accredited representative relied heavily upon the support, knowledge, and objectiveness of his advisors.



Right engine's damaged fan blades.

Several analyses and recommendation meetings were convened, some of which were held in The Hague and some in Rome. The Dutch accredited representative could not attend all the meetings in Rome, so on some occasions we were present at these meetings as replacements. We were, therefore, playing a variety of roles on different occasions throughout the investigation ranging from a subordinate role to a leadership role. We had to balance diplomacy with assertiveness and, above all, we had to keep our focus on getting to the bottom of the true causes of the event.

As this was an international investigation, the importance of a final report in the English language was apparent. Because we were more fluent in English, the union investigator and I were given the very important job of writing the report under the supervision of the IIC. The report and its recommendations would not only be important to our company but also to many other operators who had a vested interest in this very critical safety issue.

Investigator training

As illustrated by the example in Turin, proper training of airline investigators is a vital facet of the operator's flight safety program and more importantly the training should be within the reach of, and available to, all operators.

One of the most striking aspects of many formal accident investigation courses is that the bulk of such courses is not relevant to the airline investigator. Also many courses are out of the financial reach of smaller operators and those who it could be argued may need it most.

Fortunately, most airlines tend not to have accidents. If an airline does have an accident, the airline investigator will at best be an advisor and will certainly never be acting as an investigator-in-charge.

Airlines do, however, have incidents from time to time and sometimes these incidents are serious. Often, though, due to staff shortages or other investigations already in progress, the national investigation authorities do not have sufficient time or resources to investigate all serious incidents and at best are sometimes only able to give limited attention. Even though the investigation of serious incidents has been mandated in the latest version of ICAO Annex 13, the reality is that this task more often than not is allocated to the operator itself and, therefore, the quality of such an investigation depends upon the training of the operator's investigators. There is no doubt that valuable lessons can be learned from incident investigations, and we are of the opinion that there is an industrywide underestimation of the importance of well-performed incident investigations and quality report writing.

In terms of an airline safety program, it is important that

- the seriousness of an event is recognized and assessed accurately by means of a comprehensive risk-assessment program.
- the airline must be prepared to participate in investigations of serious incidents with or without the assistance of the state investigation authority.
- if the state investigation authority conducts an incident investigation, then the airline investigator should be aware of its responsibilities and entitlements. This point applies equally in an accident investigation.

We would argue that investigators should be trained how to recognize a serious incident, how to investigate a serious incident, how to write a report that supports effective recommendations, and to develop a sense of when risk should be mitigated. Equally important is the airline investigator's ability to work with other investigators and the ability to manage a small investigation team. We maintain that the proper and comprehensive investigation of incidents is vital to the improvement of safety.

In the case of Turin, the report also analyzed and produced recommendations in regard to

- fueling policy,

• crew hand-over procedures,
• preflight inspections,
• the Deicing and Quality Control Pool auditing system,
• organization and management of out station ground handling, and
• internal distribution and control of company documentation.

In view of the potential value of well-formulated recommendations that arise from a comprehensive investigation, it makes sense to give consideration to affordable and appropriate investigator training courses. We also believe that due consideration should be given to airline investigator pools or investigator exchange programs.

Our belief is that if investigator pools or exchange programs existed then several smaller airlines of limited resources and capability would benefit enormously from the opportunities—not only for their investigators to improve their skills by working along side more experienced investigators, but also that all companies would benefit from an exchange of ideas and incident investigations could be performed more thoroughly and proficiently.

Interactive and customized training benefits

In 2003 the ISIS incident investigation course was developed to train investigators in order that they may lead and manage an incident investigation and that they may be able to perform the role as advisor in an accident or incident investigation.

The specific advantages of in-house courses involved have been

• More people were trained and ready to perform investigations, safety assessments, and analysis.
• Persons were trained in the same "vein" and were therefore able to think on the same wavelength.
• Persons from several different departments were trained together, which increased their individual knowledge and understanding of one another's roles within the company.

We believe that accidents such as the one at Cali and serious incidents such as the one at Turin clearly demonstrate the very fine line between incident and accident and clearly emphasize the importance of having well-trained airline investigators.

• Better capacity and more time to concentrate on and discuss "regional" issues.
• Less costs per head for the company.
• Less down time for personnel because traveling away from the home base was not required.
• Increased flexibility for the company in case of production problems.

Why a stand-alone incident investigation course and not an integrated accident investigation course?

• Airlines have more incidents than accidents, and proper investigation of an incident can help to prevent an accident.
• Investigation training also requires consolidation, and working with other experienced investigators and advanced training is only of value after a suitable consolidation period.
• Cost, spread of costs, employees are only absent from duties for 1 week at a time instead of the usual 2 weeks or more.
• Specific learning—more concentration on the topics and disciplines that are relevant to airline operations.
• Learning over a longer period of time plus the opportunity to revise and update previous learning by doing the accident investigation training module 6 months to 1 year after the incident investigation module.

Why did ISIS set up this course, while there are already other courses available? We wanted

• to see more emphasis placed on incident investigation.
• to see the inclusion of more relevant material and to give more hands-on practice.
• this type of training to be available for all operators, large and small.
• investigators to be able to recognize the intrinsic value of other investigation reports.
• to create a course that is portable.

We believe that the delivery and teaching methods are just as important as the content of the course. Lecturers are trained in teaching skills in line with recognized university teacher training methods. The ISIS course is highly interactive, and the number of attendees is restricted to smaller groups in order to guarantee individual attention and feedback.

We place a very high value on incident investigations, not only from the cost aspect for smaller companies but also for the added value to safety that will come with comprehensive, well-performed investigations and associated quality reports.

It is often the case that many serious incidents will have the same "footprint" as an accident but that a stroke of luck or good fortune breaks the error chain and an accident is avoided.

This was seen in the case of the Fokker 70 icing incident at Turin. Many accidents, on the other hand, would have or could have been serious incidents save for one factor such as in the case of Cali when the speed brakes remained extended when the B-757 attempted to clear the high terrain. If Cali had been a serious incident and not an accident, then the investigation of this event would have been vitally important. The interesting thing, however, from our point of view is that had Cali only been an incident, the investigation may have had to have been performed by the airline itself.

We believe that accidents such as the one at Cali and serious incidents such as the one at Turin clearly demonstrate the very fine line between incident and accident and clearly emphasize the importance of having well-trained airline investigators. ◆

Flight Data—
What Every Investigator Should Know

The correct interpretation of flight data and/or audio data requires a full understanding of the entire signal path from measurement to recorder to investigator.

By Michael R. Poole, Managing Partner, Flightscape, and Simon Lie, Associate Technical Fellow, Boeing Air Safety Investigation

(This article was adapted, with permission, from the authors' presentation entitled Flight Data—What Every Investigator Should Know, *presented at the ISASI 2007 seminar held in Singapore, Aug. 27-30, 2007, which carried the theme "International Cooperation: From Investigation Site to ICAO." The full presentation including cited references index is on the ISASI website at www.isasi.org.—Editor)*

Flight data are becoming more readily accessible and are increasingly being used for investigation and airline safety programs. Modern aircraft record a huge amount of data compared to just a few years ago, but even in the most advanced aircraft recording systems, significantly less than 1% of the available data are actually recorded. The challenge of analyzing flight data is to recreate an accurate understanding of an event from that small percentage of the available data.

The scientific evaluation of data requires an understanding of the origin, or provenance, of the data and how the data were processed. Both authors have seen professional investigators reach mistaken conclusions when reviewing recorded flight data without fully understanding the origin and history.

As parameters proliferate, even the naming of parameters can lead to confusion. Consider two different parameters that are recorded on certain B-737 aircraft: *Selected Fuel Flow* and *Selected Heading*. In the former, the "Selected" indicates that multiple fuel flow readings from different sensors are available and this particular value has been judged to be the most accurate and thus has been selected for display to the flight crew. In the latter, "Selected" means the target value of heading chosen by the flight crew via the autoflight mode control panel. As these two examples demonstrate, scientific rigor requires a full understanding of the origin of flight data and how the data were processed.

It is important that investigators and airline Flight Operations Quality Assurance (FOQA) analysts appreciate the provenance of the flight data, especially when drawing substantive conclusions. There is anabundance of flight data analysis tools that are becoming progressively more automated, which in turn increases the potential to mislead.

Provenance

There are many examples where the correct interpretation of an FDR recording requires a full understanding of the provenance including the methods employed by the replay ground station. According to the *Oxford English Dictionary,* provenance is "a record of the ultimate derivation and passage of an item through its various owners." Adapted for the context of recorded flight data, the definition becomes "a record of a physical measurement or system state and the changes to that record as it passes through various system components until it is interpreted for an investigation."

Consider the "Selected Heading" example above and as shown in Figure 1. The flight crew uses the heading window on the mode control panel (MCP) to choose a flight heading. The MCP transmits this value to the flight control computer (FCC). The FCC uses the value for computing the correct flight director and autopilot behavior.

__Mike Poole__ is a principal at Flightscape, a flight sciences company specializing in flight data analysis software. He was with the TSB of Canada for more than 20 years where he served as the head of the Flight Recorder and Performance Laboratory and the Flight Recorder Group chairman on all major accidents. He also has represented Canada as the national expert panel member to the International Civil Aviation Organization's Flight Recorder Panel.

__Simon Lie__ is an associate technical fellow and air safety investigator at Boeing Commercial Airplanes. He has an academic background in composite structures and aeroelasticity and spent 10 years of his career at Boeing troubleshooting predelivery issues on the B-747, -767, and -777 aircraft. Lie led Boeing support of numerous accident investigations including Singapore Airlines B-747 Taipei 2000, China Airlines B-747 Taiwan 2002, Flash Air B-737 Egypt 2004, and Mandala Airlines B-737 Indonesia 2005.

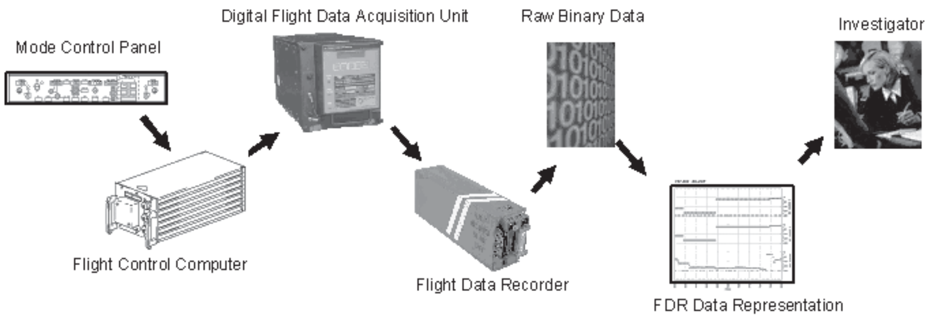


Figure 1. A graphical depiction of the provenance of the *selected heading* parameter recorded on a B-737-300 FDR. The data originate in the mode control panel and pass through a number of distinct transformations before being utilized during an investigation.

In addition, the FCC transmits the value to the digital flight data acquisition unit (DFDAU).

Continuing to follow the signal chain, we find that the DFDAU stores the values it receives from the FCC until the value is scheduled to be written to the FDR. The FDR writes the value to either magnetic tape or solid-state memory as a sequence of ones and zeros. The data are subsequently extracted and converted from raw binary format back into engineering units (i.e., degrees). The converted value is represented as a plot, table, animation, or possibly another format. Finally, the data representation is interpreted by the accident or incident investigator.

In theory, each parameter may have its own unique signal chain. In practice, parameters that have the same source often share the same chain—but not always. At each step of the chain, there is the potential for a change to the signal. Therefore, each step must be fully understood as both intended and unintended changes can affect the results.

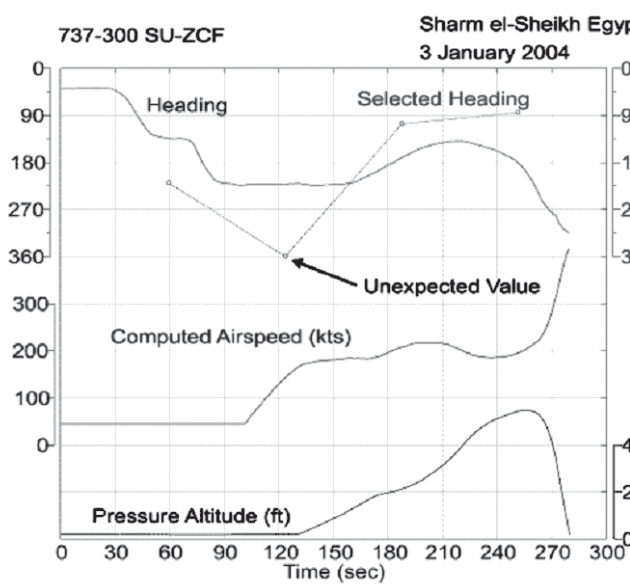


Figure 2. Altitude, airspeed, heading, and selected heading parameters during the accident flight. Selected heading is recorded once every 64 seconds. The other three parameters are recorded every second. The value at time 123 seconds is unusual as a value equal to the runway heading (220°) would be expected at this phase of flight. The unorthodox arrangement of the heading and selected heading scales (from higher values to lower values) is intentional. By convention, parameter values that result in or result from a right turn tend toward the bottom of the page. The FDR and CVR were subsequently recovered from a depth of more than 1,000 meters and provided data used during the investigation. The airplane began the left turn but then rolled out of the left turn and into a right bank that eventually reached 110° right bank. A recovery attempt was made but was not completed before the airplane descended into the Red Sea.

B-737-700 example

On Jan. 3, 2004, about 02:45:06 UTC, 04:45:06 local time, Flash Airlines Flight FSH604, a Boeing 737-300, Egyptian registration SU-ZCF, crashed into the Red Sea shortly after takeoff from Sharm el-Sheikh International Airport (SSH) in south Sinai, Egypt. The flight was a passenger charter flight to Charles de Gaulle Airport (CDG), France, with a stopover at Cairo International Airport (CAI) for refueling. Flight 604 departed from SSH Airport with 2 pilots (captain and first officer), 1 observer, 4 cabin crew, 6 off-duty crew members, and 135 passengers on board. The airplane was destroyed due to impact forces with the Red Sea with no survivors.

The airplane had departed from SSH Runway 22R and was airborne at 02:42:33 UTC, approximately 2½ minutes prior to the crash, and had been cleared for a climbing left turn to intercept the 306 radial from SSH VOR station located just north of Runway 22R.

The FDR and CVR were subsequently recovered from a depth of more than 1,000 meters and provided data used during the investigation. The airplane began the left turn but then rolled out of the left turn and into a right bank that eventually reached 110° right bank. A recovery attempt was made but was not completed before the airplane descended into the Red Sea.

The FDR recorded that the departure was flown with the use of the captain's and first officer's flight directors in heading select mode. In this mode, the flight director provides roll guidance to turn the airplane toward and hold a "selected heading" set by the flight crew on the mode control panel. Accordingly, investigative attention turned to the recorded values of selected heading on the FDR.

Figure 2 depicts the airplane heading, selected heading, altitude, and airspeed during the accident flight. Heading, computed airspeed, and altitude are recorded each second. Selected heading is recorded once every 64 seconds. Standard practice calls for setting the selected heading equal to runway heading during take off. At time 59 seconds, before the airplane turns onto the runway, the recorded value of selected heading was 220° (runway heading) as expected. At time 123 seconds, just prior to rotation, the recorded value was 360°.

Later during the flight, the recorded val-

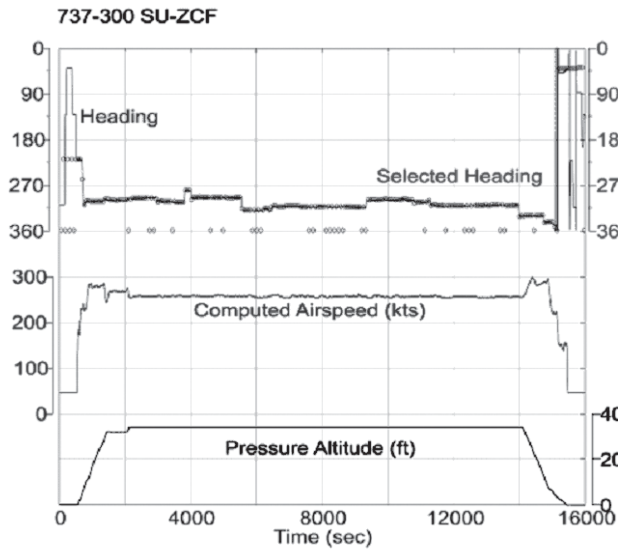


Figure 3. Altitude, airspeed, heading, and selected heading parameters during an earlier flight. Although selected heading generally follows actual heading as would be expected, there are repeated instances where unexpected values of 360° are recorded.

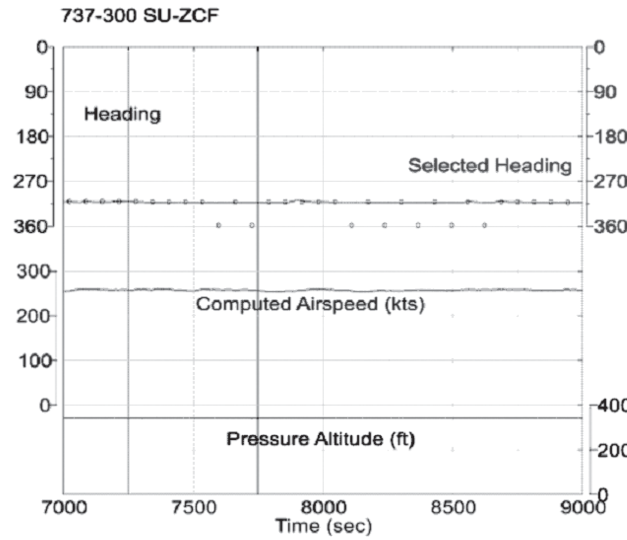


Figure 4. A portion of the same flight depicted in Figure 3 (note change in time scale). The unexpected 360° values of selected heading alternate with values coinciding with the actual airplane heading (expected values).

ues were to the left of the airplane heading, as would be expected during a left turn. The 360° value was unusual as the expected value would still be runway heading at this point of the takeoff roll. The recorded selected heading data could have indicated an unusual procedure by the flight crew, a malfunction of the mode control panel or flight control computer, or something else. Thus, one focus of the investigation was to understand the actual reason for the unusual reading.

When examining unexpected FDR data, a common practice is to use the entire 25-hour record to determine if the unusual behavior has been present on previous flights. Figure 3 depicts the same four parameters from an earlier flight recorded on the FDR. The recorded values of selected heading generally followed the actual heading (as expected), but there were repeated instances where the two differed and the selected heading was recorded as 360°. During some of the times that the 360° values were recorded, the airplane was flying on a heading of approximately 315° with the autopilot engaged in heading select mode. With the selected heading 45° to the right of the actual heading, the airplane would have been expected to begin a right turn toward 360°. However, no such behavior was observed in the recorded data.

Figure 4 depicts a portion of the same flight as shown in Figure 3 at a different time scale. The unexpected 360-degree values can be seen to alternate with values coinciding with the actual airplane heading.

A common practice among DFDAU manufacturers is to use alternating patterns to indicate errors in the FDR data. For example, "stale data" occur when a source stops transmitting data to the DFDAU or the transmitted data are not received by the DFDAU. Consultation with the manufacturer of the DFDAU confirmed that the alternating pattern observed in the FDR data from the accident flight was an error code indicating "stale data," which originated in the DFDAU. The stale data error code is an alternating sequence of 4095_{10} counts (i.e., 111111111111_2) and the last value received. For selected heading, 4095_{10} counts converts to 360°, therefore the stale data error code consists of recorded values of 360° alternating with the last value received. If the inquiry had ended here, one might conclude that the FCC had malfunctioned as evidenced by the apparent lack of selected heading transmission to the DFDAU. Such a conclusion would be incorrect.

In addition to the 25 hours of FDR data available from the accident airplane, the Egyptian MCA provided 25 hours of FDR data from the sister ship. An examination of that data confirmed the same behavior—selected heading occasionally alternated between an expected value and 360°. As shown in Figure 5, the same behavior was also discovered in the selected course #1 parameter on both airplanes but not in the selected course #2 on either airplane. Based on these discoveries, the possibility arose that some sort of design characteristic was responsible for the observed data. Perhaps there was some difference in the way the selected heading and selected course #1 parameters were processed compared to the selected course #2 data that would explain the anomaly.

Accordingly, the inquiry focused on how the DFDAU detected stale data. According to the DFDAU manufacturer, stale data are detected as follows:

- The DFDAU uses an 8-bit counter to track the number of data samples it has received from the source (in this case the FCC).
- When scheduled to write a value to the FDR, the DFDAU compares the value of the counter to the value of the counter the last time a sample was sent to the FDR.
- If either the counter value or the data value is different, the DFDAU concludes the data are fresh. If both the counter value and the data value are the same, the DFDAU concludes the value is stale. After three consecutive stale samples, the DFDAU begins writing the stale data error code until either the counter value or data value change.

Consulting with the FCC manufacturer, it was determined that selected heading and selected course #1 were transmitted to the DFDAU at a rate of 20 Hz. Thus, the

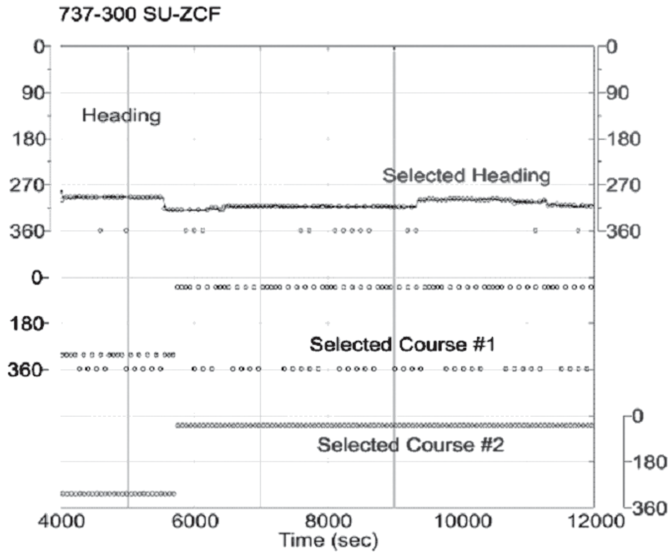


Figure 5. Similar to selected heading, unexpected values of 360° were also observed in the selected course #1 parameter but not in selected course #2. All three parameters are recorded once every 64 seconds. FDR data from the accidents airplane's sister ship exhibited the same unexpected values in the selected heading and selected course #1.

DFDAU received selected heading data once every 50 ms and transmitted it once every 64 seconds—a ratio of 1,280 to 1. In contrast, selected course #2 was transmitted by the FCC (and received by the DFDAU) at a rate of 10 Hz for a ratio of 640 to 1.

Figure 6 depicts the behavior of the 8-bit counter when utilized for selected course #2 (receive to transmit ratio of 640 to 1). The capacity of an 8-bit counter is 0-255 or 256 distinct values. During normal operation, the 8-bit counter will reach its maximum value and "roll over" back to zero at least twice and possibly three times as the 640 samples are received by the DFDAU between each sample transmitted to the FDR. Regardless of the value of the counter when a sample is transmitted, the counter will be at a different value (that differs by approximately 128 from the previous value) when the next sample is transmitted. The result is that the DFDAU can correctly determine if the data are fresh or stale.

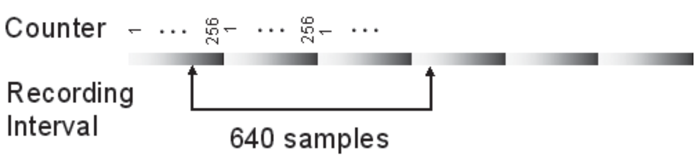


Figure 6. Behavior of an 8-bit counter when the receive-to-transmit interval is 640 to 1 as is the case for selected course #2. The capacity of an 8-bit counter is 256[5]. During normal operation, the counter will "roll over" twice (or possibly three times) between each transmission. Regardless of the value of the counter when a sample is transmitted, the counter will be at a different value (that differs by approximately 128 from the previous value) when the next sample is transmitted with the result that the DFDAU correctly detects that the data are fresh.

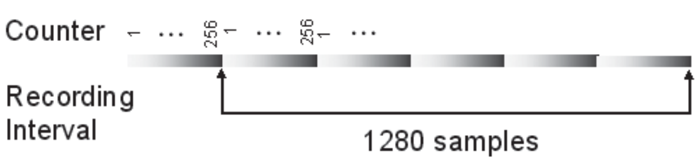


Figure 7. Behavior of an 8-bit counter when the receive-to-transmit interval is 1,280 to 1 as is the case for selected heading and selected course #1. The counter will roll over exactly five times between each transmission. The result is that the DFDAU incorrectly detects that the data are stale during normal operation.

Applying the same analysis to selected heading and selected course #1 yields a different result. Figure 7 depicts the situation when the ratio of receive-to-transmit interval is 1,280 to 1. In this case, the counter rolls over exactly five times between each transmittal to the FDR. Normal operation will result in the counter value being the same when successive samples are transmitted to the FDR. If the parameter value has not changed, the DFDAU will incorrectly detect that the data are stale, even though the correct number of samples (1,280) has been received.

The anomalies in the selected heading and selected course #1 parameters occurred frequently but not in every instance during which the above conditions are met. The last step in the inquiry determined that the exact receive-to-transmission ratio depended upon the relative timing between the FCC internal clock and the DFDAU internal clock, known as jitter. Occasionally, the DFDAU would detect 1,279 or 1,281 samples instead of 1,280 in which case the data would be treated as fresh.

Once the behavior of the stale data detection algorithm was understood, it was a simple matter to correct the FDR data to accurately reflect the selected heading values transmitted by the FCC. The DFDAU will only detect stale data if the parameter value itself is unchanged. Therefore, it was possible to conclude that the selected heading transmitted by the FCC that resulted in the 360° value recorded on the FDR must have been the same as the previously recorded value—220, the runway heading. The investigation concluded that the anomaly in the stale data detection capability of the DFDAU was responsible for the unexpected value of selected heading recorded on the FDR and that the actual value of selected heading at this time was 220°. The corrected value shown in Figure 8 (see page 30) depicts the data used for the analysis portion of the investigation.

As often occurs, this investigation uncovered a finding not related to the accident itself—that the DFDAU did not correctly process data when the receive interval-to-transmit interval ratio was a multiple of 256. A full understanding of the provenance of the FDR data allowed for the correct interpretation of that data for subsequent use in the analysis of the accident.

Every investigator or analyst who uses flight data should know that the correct interpretation of flight data requires a full understanding of the provenance of the data. Each step in the signal chain from measurement to transmission, recording, decoding, conversion, and the final representation can introduce unintended changes and thus the potential for error. The example discussed above demonstrates unintended changes introduced on board the accident aircraft. Such unintended changes can also occur during the subsequent recovery and conversion processes. Determining the provenance of *(continued on page 30)*

'Investigation: The Art and the Science'

ISASI 2008, the Society's 39th annual international seminar on air accident investigation, is now open for registration, according to Barbara Dunn, seminar chairperson and president of the Canadian SASI (CSASI), which is hosting the event to be held in Halifax, Nova Scotia, September 8-11. In addition, the Seminar Committee is honoring the 100th anniversary of the construction of the Silver Dart through its representation in the ISASI 2008 logo. The aircraft, credited with completing the first controlled power flight in Canada and the British Empire, was built in 1908 by the Aerial Experiment Association chaired by Dr. Alexander Graham Bell. John A.D. McCurdy piloted the historic flight on Feb. 23, 1909.

The seminar program registration fee (in U.S. dollars) by August 10, is member, $525; student member, $200; non-member, $570. If registration is made after August 10, the fees are $575, $225, and $625, respectively. Day pass fee for any of the three days is $200 by August 10, after that date $225. The member fee for either of the two September 8 tutorials is $125 by August 10 and $150 after that date; student member, $75 and $100. The companion fee is $320 by August 10 and $350 after that date. Registration cancellations made before July 10 will incur a $10 fee. Cancellations between July 27 and August 10, will incur a $75 fee. There will be no refund of fees for cancellations after August 10.

The Canadian Society has established a detailed and easy-to-manage website accessible through the ISASI website, www.isasi.org. All areas of delegate interest are easily identified and accessed on the site. A seminar registration form may be found on the website and it may be submitted electronically. A copy of the seminar registration form is also reprinted on page 25. Either registration form may be downloaded or clipped out and mailed to ISASI Seminar Registration, P.O. Box 16032, Albuquerque, NM, 87191 USA.

The seminar will be held at the Halifax Marriott Harbourfront Hotel. The ISASI delegate room rate is $185 Canadian for either a single or double and is subject to taxes. The special rate is valid to August 7 and is available from September 2-16. No provisions exist for special rates on upgrade rooms. Rated as a AAA 4-Diamond hotel, it is situated in the heart of downtown, only steps away from the city's top attractions, including the business district and World Trade & Convention Center. The hotel is known for its upgraded business amenities, as well as 17,000 square feet of flexible meeting and social-event space. Delegates should deal directly with the Halifax Marriott regarding their accommodation arrangements. The hotel registration form is available through a link accessed through the ISASI 2008 seminar website (www.isasi.org).

Program plan

The seminar program will follow the established format of past seminars, with 1 day devoted to two tutorial workshops and 3 days of technical paper presentations in plenary session. National society, committee, and working group meetings will also be scheduled. ISASI 2008 carries the theme *"Investigation: The Art and the Science,"* that, says Jim Stewart, technical program chairman, "reflects the complexity and challenge of today's investigation process. As science advances aviation technology, that same science introduces the need for new techniques and support systems to ensure a comprehensive and professional investigation. The art of successful investigation requires the creative application of personal knowledge and skills and the development of new concepts to keep pace with a rapidly changing industry world wide."

He adds, "The Seminar Committee was looking for papers that would deal with the hard and soft aspects of investigation, in particular, new ideas that will lead us to improved investigation whether it is techniques, management, process, technology, factual analysis, high tech or low tech. The subject matter could be as broad as the imagination or expertise of the presenter. The Technical Committee wanted to reach beyond the normal papers and explore new ideas. We were also very interested in hearing from full-time investigators or agencies that have recent experience with new techniques or processes and their experience in applying them. Some 'soft side' subjects we were interested in were subjects ranging from dealing with the news media, relatives, and interview techniques."

The Committee has received more than 40 proposals for papers from a number of qualified speakers on a wide range of subjects. About 25 of these proposals will be presented in Halifax following a thorough assessment by the ISASI 2008 Papers Selection Committee, which reflects the international aspect of ISASI. Joining Stewart as members of the Committee are Barbara Dunn (Canada), Seminar Committee chair; Nick Stoss (Canada), tutorial chair; Ron Schleede (USA); Marcus Costa (ICAO); Claudio Pandolfi (Chile); Wing Keong Chan (Singapore); Danny Ho (Taiwan); Martine Del Bono (France); David King (UK); and Michael Walker (Australia).

The 1-day tutorial sessions will include two workshops. The first will center on Safety Management Systems and the

39th Annual International Society of Air Safety Investigators Seminar

Sept. 8–11, 2008, Marriott Harbourfront Hotel, Halifax, Nova Scotia, Canada

Delegate Registration Form and Fee Summary (US$)

Yes, please register me for the 39th Annual International Society of Air Safety Investigators Seminar! You can register by e-mailing, mailing, or faxing this completed form to the information below. Please complete one form for the primary individual attending. Exhibitors and companions have a separate registration form. **Note**: Please print all information on this form. This form may be reproduced as necessary. Cancellations made before July 10, 2008, will incur a $10 fee. Cancellations between July 27, 2008, and Aug. 10, 2008, will incur a $75 fee. There will be no refund of fees if cancelled after Aug. 10, 2008. However, substitutions are permitted at any time. Make sure to include the fees for any optional programs in the total amount being paid.

Please Complete All Areas as Appropriate **Is this Your First Seminar?** ❑ Yes ❑ No

ISASI Member? ❑ Yes ❑ No If yes, please complete the member information below:

Member number ____________ Society, chapter, or region: ____________

❑ Mr. ❑ Ms. ❑ Mrs. ❑ Dr. ❑ Other (If "other" please specify) ____________

First name ____________ Middle initial ____________

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Company or organization ____________ Position, title, or job ____________

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E-mail address ____________

Special meals request (All requests will be honored if possible) ____________

Name and company as you want it on the badge: ____________

Registration type	Before Aug. 10	After Aug. 10
❑ ISASI member	US$525	US$575
❑ ISASI student member	US$200	US$225
❑ Not an ISASI member	US$570	US$625
Delegate nominated by sponsor (free)		

The above registration includes the reception (Mon.), fun night (Tues.), and banquet (Thurs.). Please check below if not attending:

❑ Reception ❑ Fun Night ❑ Banquet

❑ Day pass only (per day) US$200 US$225

Check day(s): ❑ Tuesday ❑ Wednesday ❑ Thursday

❑ Banquet only (US$100) ❑ Tuesday fun night (US$100)

❑ Welcome reception (Monday) (US$90)

Optional programs	Before Aug. 10	After Aug. 10
❑ **Tutorial** (Monday, Sept. 8)	US$125	US$150
❑ **Tutorial** (student member)	US$ 75	US$100

Please select one tutorial:

❑ Tutorial #1—Conducting Safety Investigations in a Safety Management (SMS) Environment

❑ Tutorial #2—Investigating General Aviation Accidents

❑ **Companion Program**

(per person) US$125 US$150

Note: Please fill out the Companion registration for each companion.

# of Companion Programs ______

Billing information

❑ **Charge my credit card:** ❑ AmEx ❑ VISA ❑ MasterCard Name on card ____________

Card number ____________ Expiration date ____________ Card code ____________

❑ **Send by mail:** ❑ Payment by check ❑ Company purchase order P.O. # ____________

TOTAL IN US$ ____________

Note: Credit card name must be listed on the card. Card billing address must match address listed above in registration. The card code is a four-digit number on the front of an American Express card or a three-digit number on the back of a VISA or MasterCard.

Mail to: ISASI Seminar Registration
P.O. Box 16032, Albuquerque, NM 87191 USA

TEL: +1 (888) 292-2129 (US and Canada)
TEL: +1 (505) 299-1690

FAX to: +1 (505) 292-2017
E-mail to: sharon.morphew@scsi-inc.com

Signature (required for credit card) ____________ second will deal with investigating general aviation accidents.

Tutorial No. 1, "Conducting Safety Investigations in a Safety Management Systems (SMS) Environment," will seek to answer the questions "What will the impact of SMS be on safety investigations?" and "How do we investigate under the shadow of SMS?" The seminar website contains more information on the contents of the tutorials.

Social programs

In keeping with ISASI tradition, the seminar social program will start with a welcome reception on Monday evening, September 8. This is an ice-breaker social, providing an opportunity to meet with old and new friends. On Tuesday evening a special dinner is planned that will allow attendees to experience some Canadian history at the Pier 21 National Historic Site. This Canadian equivalent to Ellis Island welcomed newcomers to Canada from 1919 to 1972. Immigration databases, tourist information, and gift and coffee shops are a few of the attractions that await guests at the Chrysler Canada Welcome Pavilion. Guests will enjoy a reception in Exhibition Hall before being seated in Heritage Hall for a traditional East Coast lobster dinner.

Wednesday evening will be a free night permitting attendees to explore the many fine restaurants found in Halifax. The Awards Banquet, at which ISASI's Jerome F. Lederer Award presentation is made, will be held on the Thursday evening at the Harbourfront Marriott. The usual post-seminar optional tour on Friday is not being offered.

Companion's Program

The Companion's Program, organized by Gail Stewart and Paula Demone, includes a deluxe Halifax City tour on Tuesday and a visit to the South Shore on Wednesday. Both are all-day tours and promise exciting historical narratives. Kilted guides will no doubt relate stories of the days of rum running and privateering as they move through the city streets on Tuesday. The tour will travel to Fisherman's Cove for a two-course lunch enhanced by views of Nova Scotia's Eastern Passage.

On Wednesday, the group will tour the rugged and beautiful South Shore of Nova Scotia. The first stop is Lunenburg, which has been called "the prettiest town in Canada." Settled in the mid 1750s by Germans and Swiss, its citizens still retain one of the most interesting accents in North America. Now a bustling fishing port, the town's distinctive architecture and extraordinary scenic beauty are a colorful reminder of its maritime heritage.

After lunch at Lunenburg's The Old Fish Factory comes a quick stop at Mahone Bay with its many cottage industries, craft shops, and famous "Three Churches." Then it is on to Peggy's Cove, an artists' and explorers' paradise for well more than 150 years. This picture-postcard village stands on solid rock above the crashing surf. The coastline is famous for pirates, shipwrecks, rum running, and sunsets. Full details of the Companion's Program are available on the ISASI 2008 website.

Nova Scotia fast facts

Capital city—Halifax Regional Municipality.

Population—Halifax Regional Municipality 382,203, Nova Scotia 934,405.

Languages—The official languages of English and French are spoken throughout Nova Scotia.

Time zone—Nova Scotia is on Atlantic Daylight Time, which is 4 hours earlier than Greenwich Mean Time and 1 hour later than North America's Eastern Time Zone. Daylight Saving Time took effect the second Sunday of March and continues to the first Sunday of November.

Climate and weather—Average daily temperatures in spring are from 2° to 9° C (35.6° to 48.2°F); summer from 16° to 24° C (60.8° to 75.2°F); fall about 18° C (64.4°F); winter about -3° C (26.6°F). Weather forecasts are given in Celsius measurements. For approximate temperature conversion: Fahrenheit to Celsius: subtract 30 and divide by 2. Celsius to Fahrenheit: multiply by 2 and add 30.

Airports—Most air traffic comes through Halifax Stanfield International Airport, which is the Atlantic Canadian center for domestic, regional, and international flight service. With more than 600 flights a week, travelers can reach Halifax on direct flights from many Canadian, U.S., European, and Caribbean destinations. Air carriers serving Halifax include Air Canada, Air Canada Jazz, WestJet, Continental Express, Delta, United, Northwest, American Eagle, Air St. Pierre, Condor, Zoom, Go Travel Direct Vacations, Provincial, Sunwing, and Skyservice.

Customs and immigration—Immigration regulations: American citizens (or permanent residents) entering Canada by air require valid passports, and as of January 31 valid passports are required when entering by land and sea. Visitors from a country other than the United States must carry a valid passport and, in certain cases, a visa to be eligible to enter Canada. All persons entering Canada must fill out a declaration for Canada Customs.

Currency—Canada's currency is based on the decimal system, with 100 cents to the dollar.

Sales tax and rebates—The harmonized sales tax (HST) is applied at a single rate of 13% to a base of goods and services. Foreign visitors may be entitled to claim a rebate of the HST paid. Accommodations in Halifax charge a hotel levy of 2% on room rates to assist in marketing Halifax as a business and leisure destination.

Hospital/medical services—Visitors to Canada are strongly urged to obtain

2007 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 38th International Seminar*, held in Singapore Aug. 27-30, 2007, by downloading the information from the appropriate section of the ISASI web page at http://www.isasi.org. The seminar papers can be found in the "Members" section. Alternatively, active members may purchase the *Proceedings* on a CD-ROM for the nominal fee of $15, which covers postage and handling. Non-ISASI members may acquire the CD-ROM for a US$75 fee. A limited number of paper copies of *Proceedings 2007* 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.

health insurance before leaving their home country. Canadian hospital and medical services are excellent, but a hospital stay can be costly without adequate insurance coverage. Visitors taking prescribed medications are advised to take a copy of the prescription should it need to be renewed during the trip. ◆

ISASI Reachout Enters 8th Year in Need of Funds

It may seem hard to believe but on May 7, the ISASI Reachout program enters its eighth year of operation. During that time, volunteer instructors have delivered 25 successful workshops around the world. Ladislav Mika, the first host, and Prague, the Czech Republic, where the first workshop was held in May 2001, will forever be linked to the success of the Reachout program.

The past 12 months saw a flurry of activity as ISASI instructors traveled extensively around the world—

ISASI ROUNDUP

Continued . . .

• Reachout #21 Kiev, Ukraine, October 2007
• Reachout #22 Santiago, Chile, November 2007
• Reachout #23 Karachi, Pakistan, November 2007
• Reachout #24 Abu Dhabi, UAE, November 2007
• Reachout #25 Brisbane, Australia, March 2008

Currently scheduled workshops include—

• Reachout #26 Seattle, USA, April 2008
• Reachout #27 Mumbai, India, April 2008
• Reachout #28 Bahrain, UAE, May 2008
• Reachout #29 Karachi (Unscheduled)

But ISASI Reachout Committee chairman, Jim Stewart, sees problems in the future for the Reachout program if funds are not received to replenish the main Reachout account. "We have been very successful in obtaining local sponsorship for individual workshops," Stewart said recently. "We have been particularly blessed with dynamic individuals volunteering to host our workshops and with national and regional airlines providing air travel." Stewart pointed out that their support has been considerable in many cases and without that support the program could not have been able to sustain the level of activity it has to date. He concluded, "But our ability to support our instructors is not as strong as I would like.

"We need to top up our emergency fund to ensure that our instructors are not paying their own way," Stewart said. "That Reachout fund is kept in a separate account at the ISASI head office. We use that fund to reimburse instructors when local sponsors can not cover all of the associated costs," Stewart pointed out, "and that fund is running dangerously low as a result of our activity levels." Stewart also pointed out that access to the emergency funds is strictly controlled with both he and the ISASI treasurer having to jointly approve expenditures before the fact.

ISASI Reachout was originally conceived as a way for ISASI corporate members to participate in the work of the Society. To a great extent, some ISASI member corporations have responded in kind and provide access to airline seats, free access to documents and manuals, use of organizational materials and staff, and many other small and large contributions. Stewart said, "Without the continued support of sustaining organizations like ICAO, the Air Line Pilots Association, and Continental Airlines, our job would be much more difficult."

ISASI Reachout needs to increase the number of sustaining sponsors and needs to receive additional "one time" donations

New Members

CORPORATE

Finnish Military Aviation Authority
Major (Eng.) Kimmo T. Nortaja, Leading Aviation Accident Investigator
Mikko T. Hietanen, Chief of FAIF Flight Safety
Northwest Airlines
Lisa G. Brockenbrough, Director, Flight Safety and Industry Affairs
Todd Tilbury, Manager, Flight Safety
Dombroff Gilmore Jaques & French P.C.
Mark A. Dombroff, Managing Partner
Dane B. Jaques, Partner
General Aviation Manufacturers Association
W. Casey Kinosz, Manager of Operations
Jens C. Hennig, Vice-President of Operations

INDIVIDUAL

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Al Marzouqi, Fouad, B., Abu Dhabi, United Arab Emirates
Al Said, Saud, T., Sharjah, United Arab Emirates
Al-Awadhi, Kamil, H., Quadsiah, Kuwait
Alegado, Jaime, V., Doha, Qatar
Anglin, Lori, M., Renton, WA, USA
Awbery, Natalie, Godalming, Surrey, United Kingdom
Balentine, Chad, J., Winchester, VA, USA
Barros, Andrés, Santiago, Chile
Barth, Thomas, H., Denver, CO, USA
Benassi, Stefano, VR, Italy
Bonnassie, Fabien, Montreuil, France
Boyd, Rodney, L., Wylie, TX, USA
Cabel Francis, Abu Dhabi, United Arab Emirates
Chen, Felix, S.K., Singapore
Chiang, Vin, C., Daytona Beach, FL, USA
de Kock, André, L., Montréal, Canada
De La Vauvre, Gaetan, Evanston, IL, USA
De Waal, Johan, G., Abu Dhabi, United Arab Emirates
Decatur, Danielle, M., Ocean, NJ, USA
Dyer, Brian, R., Daytona Beach, FL, USA
Eisenman, Nathaniel, B., Manassas, USA
Elgindi, Hisham A. Aziz, Abu Dhabi, United Arab Emirates
Engroba, Juan, D., Buenos Aires, Argentina
Farmiga, Samuel, R., West Chester, OH, USA
Fragoso, Jefferson, V., Sao Paulo, Brazil
Franklin, Ryan, H., Ormond Beach, FL, USA
Gipson, Paul, Scottsdale, AZ, USA
Goetz, Jean-Baptiste, Abu Dhabi, United Arab Emirates
Graydon, Mike, Abu Dhabi, United Arab Emirates
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Jay, Susan (Sue), M., Orange Park, FL, USA
Kelman, Sarah, J., Cambridge, United Kingdom
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Kwajan, Francis, A., Grand Central Station, NY, USA
Labrucherie, Stephan, Abu Dhabi, United Arab Emirates
Lammas, Janet, I., Wellington, New Zealand
Mayfield, Richard, F., Renton, WA, USA
Miller, Andrew, B., Christchurch, New Zealand
Miranda, Ray, M., Kajang, West Malaysia
Moussa, Ali, M., Beirut, Lebanon
Naseer, Ahsan, Abu Dhabi, United Arab Emirates
Nitta, Takashi, Toyonaka, Osaka, Japan
Noe, II, Ronald, E., Wichita, KS, USA
Nutter, Christopher, G., Federal Way, WA, USA
Ordor, Maria, U., Mafoluku-Lagos, Nigeria
Pinzón Müller, Eduardo, Bogota, Colombia, South America
Pooley, Edward, J., Isle of Man, British Isles
Qarashi, Baha, G., Abu Dhabi, United Arab Emirates
Richter, Mark, W., Hanover Park, IL, USA
Rigby, Kevin, T., Pensacola, FL, USA
Rivera-Martinez, Alimael, Prescott Valley, AZ, USA
Rogachuk, Ted, M., Bay Village, OH, USA
Ronaldson, George, Aberdeen, United Kingdom
Ross, Cameron, C., Southlake, TX, USA
Satti, Juan, A., Castelar, Argentina
Savage, Eric, R., Prescott, AZ, USA
Schonhardt, Carlos, F.G., Rio De Janeiro, Brazil
Senthil, M.S., Gopalakrishnan, Seeb Int'l Airport, Sultanate of Oman
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Skoor, Erich, J., Prescott, AZ, USA
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Stauffer, Kent, M., Stow, OH, USA
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Torres, Roberto, H., Ormond Beach, FL, USA
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Yusof, Mohd Hisham Md., Abu Dhabi, United Arab Emirates
Zanolli, Stefano, Roma, Italy
Zwager, Finn, Dubai, United Arab Emirates ◆

REMINDER

ISASI annual dues were due in January. For those members who may not have yet made the payment, please contact Ann Schull at isasi@erols.com or call 703-430-9668 to make payment arrangements. If payment is not received, the affected member will be placed in an inactive status. ◆

from a broader base of corporations. "When we started the Reachout program, we established a one-time Charter Sponsor category for original sponsors," Stewart said.

"We can't bring that category back, but we will create a new category, 'Sustaining Sponsor,'" he said. "Sustaining Sponsors are those sponsors we can count on to be there when needed throughout the year."

For those corporations or individuals who wish to contribute to the Reachout program, even a one-time contribution will help, no matter how large or small. Contributions should be payable to ISASI Reachout and sent to ISASI headquarters at Park Center, 107 East Holly Ave., Suite 11, Sterling, VA, 20164-5405.

In a final comment, Stewart again thanked the instructors, the local hosts, and the current Sustaining Sponsors for their continued support. "They are the reason we are here today," he said. "Their contribution has been large, their commitment strong. You can help by joining the ISASI Reachout sponsorship group as a 'Sustaining Sponsor' or a one-time contributor. Make your contribution today," he concluded. ◆

Arizona Chapter Continues Expansion

The student section of the Arizona chapter continues to expand. Chapter President Bill Waldock says, "We currently have 16 active members, with a big push for them to join the International Society. Currently, the students meet every 2 weeks in the Robertson Aviation Safety Center at Embry-Riddle's Prescott Campus. We have had several guest speakers, including Prof. Denny Lessard and FAA Maintenance Inspector Pete Kelly."

In November 2007, the Chapter sponsored a presentation to the campus by retired NTSB senior air safety investigator Greg Feith. Members from the Chapter have been assisting regularly in maintaining and refurbishing accident scenarios in the Aircraft Accident Laboratory. The Chapter is sponsoring a trip to Williams-Gateway Airport in May for those members who would like to experience an altitude chamber ride. The student section has just held officer elections, and Erich Skoor (ST5519) will be the new president.

On Nov. 16, 2007, the Chapter conducted an expedition to the World War II B-24 crash site on Humphries Peak near Flagstaff, Ariz. This was the single largest trip to the crash site, with 35 people participating. The aircraft crashed during a night training mission in September 1944. All eight airmen aboard were killed. The wreckage is located between 11,000 and 11,500 feet on the mountain and, due to the terrain, is difficult to access.

Most of the wreckage is still there, and one of the long-term projects the Arizona Chapter has undertaken is to conduct periodic surveys of the wreckage layout and positions of major pieces.

Waldock says, "We have been up there five previous times, but this time we had a very significant occurrence. Our student section president, Cavi Freeland, was helping examine an area where components from the front of the fuselage had been identified. She noticed an odd piece just below the surface of the soil and teased it up with a finger. It was a gold airmen's style ID bracelet piece with the name 'Ray Shipley' engraved on one side and 'DRU' on the other. The crew manifest shows Flight Officer Ray Shipley as the 'second pilot' on the aircraft. Research has shown that his wife's name was "Drucilla" and that he has living relatives in Garland, Tex. Craig Fuller of Aviation Archaeology Investigation and Research has assisted with the provenance and record search by which we have been able to document what is known about this long-lost young pilot. We are currently making plans to return the ID to Shipley's family."

New Book Outlines 'The Limits of Expertise'

The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents, by ISASI member Dr. Loukia Loukopoulos and coauthors Benjamin A. Berman and R. Key Dismukes, argues that human skill and vulnerability to error are closely linked.

In paperback, it is 352 pages, published

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by Ashgate Publishing Company. It is available through Amazon.com, where sufficient reviews are also posted. One of those reviews, by Benjamin Daley, cites it as an "Outstanding and original book… that show[s] that the presence and interaction of factors contributing to error is probabilistic rather than deterministic."

Stephen Wilkinson in his review of the book published in *Air and Space* magazine noted that the book "simply examines the 19 serious accidents suffered by major U.S. air carriers between 1991 and 2000 in which the NTSB cited crew error as playing a central role."

Daley, in his review, says: "While the NTSB must determine the probable cause of each specific accident, the authors take a different approach: would other pilots be vulnerable to making the kinds of errors made by the accident crew and, if so, why? This original approach reveals factors that make all pilots vulnerable to specific types of error in certain situations. In adopting this approach, the authors challenge the assumption that, if expert pilots make errors, this is evidence of their lack of skill, vigilance, or conscientiousness. Instead, the authors emphasize the interactions of subtle variations in task demands, incomplete information available to pilots, and the inherent nature of skilled performance."

He adds, "The book will be informative for diverse readers in the air transport industry, including operational staff, researchers, safety analysts, accident investigators, designers of systems and procedures, training providers, and students….

"The main significance of this book is in its re-framing of the causes of airline accidents: the authors argue that, if we must continue to conceive of airline accidents in terms of deficiency, then that deficiency should be attributed to the overall air transport system. Such an approach can contribute to aviation safety by providing a foundation for improving equipment, training, procedures, and organizational policy. In so doing, it is possible to reduce the frequency of 'system accidents' and to devise adequate protection against the types of errors to which many, if not all, pilots—as well as many other experts—are vulnerable." ◆

Flight Data—What Every Investigator Should Know *(from page 23)*

each parameter and understanding the capabilities and replay processes within the analysis software is a necessary step in interpreting flight data. ◆

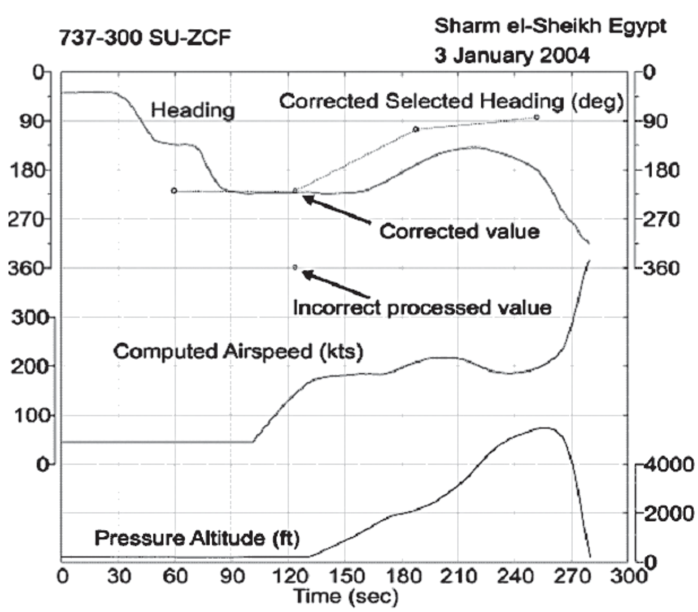

Figure 8. The same data as depicted in Figure 1 corrected to account for the anomaly discovered in the way the DFDAU processed the selected heading data. These were the data used for the analysis portion of the investigation.

(Space restrictions required deletion from the authors' presented paper their discussion dealing with the processing of flight data through two methods: Converting the binary ones and zeros into engineering units data and producing comma separated variables files and interactively working with the binary data on a demand basis. The unused material may be viewed on the ISASI web page in Proceedings 2008, page 95.—Editor)

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University of NSW Aviation
University of Southern California
Volvo Aero Corporation
WestJet ◆

WestJet Navigates the SMS Airways

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

Based in Calgary, Alberta, WestJet is Canada's original low-fare airline. WestJet took flight on Feb. 29, 1996, serving five destinations with three Boeing 737-200 aircraft and 220 employees. As of Nov. 30, 2007, WestJet has grown, offering scheduled and charter service to 38 cities across North America and the Caribbean with a fleet of 70 Boeing "next generation" 737 aircraft and a team of more than 6,700 employees.

WestJet's fleet is the most modern and efficient in North America, featuring blended winglets on all B-737-700 and B-737-800 aircraft that minimize fuel consumption and environmental impact. The company has plans to grow its fleet to more than 100 aircraft by 2012.

The company has experienced exponential growth over its short 11½ years in operation. Year 2006 revenue was reported at $1.8 billion, available seat miles at 12.5 billion, and revenue passenger miles at 9.8 billion. More than 10 million guests (known as passengers with most other carriers) were carried in 2006.

WestJet credits its business success in large part to the power of its positive corporate culture. The work environment is positive, with management empowering its people to make the best decisions for the company, its guests, and its shareholders. WestJet's people-oriented environment has been a key factor in its successful implementation of Safety Management Systems (SMSs) on which it embarked in 2005 under the Canadian aviation regulations. Throughout the last 2 years, WestJet has documented existing safety management processes, implemented new ones, and built an infrastructure to support all SMS elements. Full SMS implementation is scheduled for the autumn of 2008.

A key milestone was the deployment of the company safety database in April 2006. Hosting more than 60 users, the safety database supports WestJet's SMS processes, which manage both proactive and reactive safety reports in a similar manner. Other database features include online safety reporting, corrective action tracking, permanent occurrence and investigation logs, data analysis tools, and scheduling of audits and repetitive tasks.

Common standards for operational risk management have been implemented across the company. Once a hazard is identified, it receives an initial risk classification that drives the follow-up process and time line. Risk classifications are validated by expert consensus or through full investigations, which are required for all elevated risk reports.

A typical investigative follow-up sees a department safety team log the occurrence report, communicate with the reporter, assign an initial risk rating, conduct an investigation, convene a safety review team, and publish a report of findings and causes. Following this process, a management representative reviews the report and implements corrective actions, as required, according to time lines specified in the company safety manual. Follow-up assessment of corrective action effectiveness is then conducted and the entire process is closed off by the company's Safety Management Committee, which is chaired by its accountable executive.

WestJet's SMS is very specific as to the roles of the safety and leadership teams. Safety teams facilitate development, implementation, and operation of safety management processes; however, the senior leadership team retains overall responsibility for all operational risk management processes and risk control activities. SMS elements have been integrated into the company's orientation, strategic planning, and training programs. Extensive use is made of interactive computer-based training and electronic documentation so that employees throughout the network can access SMS resources and apply SMS principles in their daily activities.

With an ingrained mission to "enrich the lives of everyone in WestJet's world by providing safe, friendly, and affordable air travel," WestJet is integrating SMS throughout the organization as it strives to be the No. 1 choice for air travelers. ◆

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