ISASI FORUM

"Air Safety Through Investigation"

JANUARY–MARCH 2005

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On Dec. 16, 1997, this Bombardier RJ100 crashed while conducting an approach to a Canadian airport in poor weather. The resulting investigation resulted in a TSB Canada recommendation to "expedite the approach ban regulations prohibiting pilots from conducting approaches in visibility conditions that are not adequate for the approach to be conducted safely." (See Page 5.) Photo: TSB Canada

ISASI FORUM

"Air Safety Through Investigation"

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AIR SAFETY INVESTIGATORS
INCORPORATED AUGUST 31, 1964

A General Aviation Initiative

By Frank Del Gandio, President

Over the years, ISASI's major initiatives have been oriented toward transport-category aircraft. In that regard, I believe that we have been neglecting the major portion of this world's aircraft fleet—general aviation, which makes up around 83% of the fleet. Although it has the largest portion of the fleet, the general aviation community does not, in most cases, have the extensive safety organizations, accident investigation capacity, and safety programs that are evident, and required, in commercial aviation. The paramount importance of air safety within and related to the air carrier fleet is a given. But I do believe that ISASI can do more to help improve the safety effort of the general aviation community, without reducing our safety initiatives in the air carrier arena.

To this end, I recently appointed William (Buck) Welch of Cessna Aircraft Company to be the chairman of the newly instituted ISASI General Aviation Working Group. Buck has a very extensive background in accident investigation and safety (see "ISASI RoundUp") and is anxious to form the new Group, which will establish its agenda and issues to address.

What can you do? If you have any interest in participating in this Working Group, contact Buck (wwelsh@cessna.textron.com). The majority of this Group's activity will be done by e-mail. There will always be a Working Group meeting scheduled during the annual seminar. Your attendance at this meeting is not mandatory. Sign up today and be a part of this very prestigious and important team. Additionally, the Government Air Safety Investigations Working Group lacks a chairman and has been inactive for 2 years. If you have any interest in this activity, contact me at isasi@erols.com.

In another matter, one important byproduct of aviation accident investigation is the accident data that we create. From that data, analysts are able to discover trends that help us identify systemic safety problems. One aspect of existing accident data that has hindered safety analysis is the diverse and confusing ways all of us enter the data into our respective databases.

For instance, I looked in six different accident databases for a specific Airbus airplane, an A300-B4605R. I found it listed six different ways, some with extra dashes, some without. Some with Airbus included in the model, some with just the A. Another example of the confusion is that we all use the same occurrence categories for the most part, but they don't necessarily mean the same thing. Controlled flight into terrain in one country's database might include collisions with objects, but another country's might include just terrain. To do any sort of analysis, one has to "scrub" the data to make it standardized and consistent.

At best, non-standardized data lead to expensive data "scrubbing" or at worst inaccurate conclusions. An effort is under way to establish a data standard for all countries to voluntarily adopt. The International Civil Aviation Organization (ICAO) and the Commercial Aviation Safety Team (CAST) have jointly chartered the CAST/ICAO Common Taxonomy Team (CICTT). CICTT includes international experts from air carriers, aircraft and engine manufacturers, pilot associations, regulatory authorities, transportation safety boards, and ICAO.

According to CICTT, its goal is to develop common terms, definitions, and taxonomies for aviation accident/incident reporting systems. It has completed data standards for phase of flight, accident occurrence, and aircraft make and model. A standard for engine make and model is under way. The FAA and the NTSB are adopting these data standards, and I encourage all nations to adopt them as well.

CICTT has also developed a Master Model and a Master Series. It is a tool that helps analysts group related aircraft models. For instance, if you wanted to look at accidents involving the de Havilland 125, you may not know that that aircraft is virtually the same as the BAE 125, the Hawker Siddeley 125, the Beech 125, and the Raytheon Hawker. The Master Model groups all of these aircraft under DE HAVILLAND-DH125.

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2004 Safety Statistics in Historical Perspective

(Reprinted from Airliner Accident Statistics 2002, Jan. 3, 2003, with permission of Harro Ranter/Fabian Lujan Aviation Safety Network; copyright 1996-2003. Sources of data are regulatory transportation safety boards, including ICAO, insurance companies, and regional news media. The ASN site may be reached at www.aviation-safety.net.—Editor)

Statistical summary regarding fatal airliner accidents

The year 2004 was one of the safest years ever. The number of fatal airliner accidents of 26 was up one compared to 2003, but is perfectly in line with the continuing downward trend of the last 10 years. The number of fatalities (425) was an all-time low since 1945.

The figures exclude non-accident occurrences (hijackings, sabotage, etc.).

- The 2004 death toll of 425 was below the 1974-2003 average death toll of 1,348 casualties.
- The 2004 death toll of 425 was below the 1994-2003 average death toll of 1,191 casualties.
- The 2004 number of occupants involved in fatal airliner accidents of 610 was far lower than the 1993-2002 average of 1,586.
- The 2004 fatality rate (percentage of occupants killed in fatal airliner accidents) of 70% was lower than the 1993-2002 average of 75%.
- The 2004 number of 26 fatal airliner accidents was far below the 1974-2003 average number of fatal airliner accidents of 48.8 per year.
- The 2004 number of 26 fatal airliner accidents was far below the 1994-2003 average number of fatal airliner accidents of 42 per year.
- The 2004 number of fatal jet airliner accidents of 8 was below the 1974-2003 average of 14.2 accidents per year.
- The 2004 number of fatal prop airliner accidents of 15 was on the 1974-2003 average of 22 accidents per year.
- The 2004 number of 3 fatal piston airliner accidents was far below the 1974-2003 average of 9.1 accidents.
- The 2004 number of 3 fatal piston airliner accidents was below the 1994-2003 average of 3.7 accidents.

Accident summary

The year 2004 recorded 26 fatal airliner hull-loss accidents and an all-time low number of 425 fatalities.

Date, Aircraft, Type, Operator, Location, Fatalities

1. January 3, Boeing 737-300, Flash Airlines, Off Sharm el Sheikh, 148
2. January 13, Yakovlev 40, Uzbekistan Airways, Tashkent, 37
3. January 28, Beech 1900, Tassili Airlines, Near Ghardaia, 1
4. February 10, Fokker 50, Kish Air, Sharjah, 43
5. March 4, Ilyushin 76, Azov-Avia Airlines, Baku, 3
6. May 7, Let 410, Air Cush, Jiech, 6
7. May 12, Antonov 12, El Magal Aviation, near Dalang, 1
8. May 14, Embraer 120, Rico Linhas Aéreas, near Manaus, 33
9. May 18, Ilyushin 76, Azal Cargo, near Urumqi, 7
10. May 23, Let 410, Blue Bird Aviation, near Mwingi, 2
11. May 25, DHC-6 Twin Otter, Yeti Airlines, near Lukla, 3
12. June 8, HS-748, Gabon Express, near Libreville, 19
13. June 26, Lisunov Li-2, FLA RF, Moskva-Myachkovo, 2
14. July 12, Convair CV-440, Dodita Air Cargo, off Beef Island, 1
15. July 29, DHC-6 Twin Otter, Airlines of PNG, near Ononge, 2
16. August13, Convair CV-580, Air Tahoma, Cincinnati, 1
17. August 17, Beechcraft 99, Alpine Aviation, near Neihart, 2
18. October 5, Antonov 12, Sarit Airlines, near Higlig, 4
19. October 14, Boeing 747-200, MK Airlines, Halifax, 7
20. October 14, Canadair CRJ200, Pinnacle Airlines, Jefferson City, 2
21. October 15, Douglas DC-3, Aerovanguardia, near Medellín, 3
22. October 19, Jetstream 32, Corporate Airlines, near Kirksville, 13
23. November 18, Jetstream 31, Venezolana, Caracas, 4
24. November 21, Canadair CRJ200, China Yunnan Airlines, Baotou, 53+1
25. November 30, MD-82, Lion Airlines, Solo City, 26
26. December 11, Embraer 110, NHR Táxi-Aéreo, Uberaba, 2+1

Total 425+2 *

*425 fatalities of airplane occupants plus two fatalities on the ground

Number of accidents per manufacturer 2004-1999 (2003, 2002, 2001, 2000, 1999 figures in parentheses)

Although the total number of accidents does not say anything about the safety of an aircraft model or manufacturer, a few things about 2004 must be noted. For instance, Canadair's RegionalJet model, in service for more than 12 years now, suffered its first passenger fatality accident in airline service when a Chinese CRJ200 crashed at Baotau, killing all 53 on board.

Aérospatiale/BAC 0 (0 0 0 1 0)
Airbus 0 (0 0 1 2 0)
Antonov 2 (3 5 2 5 3)
ATR 0 (0 2 0 0 2)
BAC 0 (0 1 0 0 0)
Beechcraft 2 (2 1 1 1 3)
Boeing 2 (3 7 6 3 5)
BAe/Avro 2 (1 0 1 2 1)
Canadair 2 (1 0 0 0 0)
CASA 0 (0 0 1 0 1)
Consolidated 0 (0 1 0 0 0)
Convair 2 (1 0 0 0 0)
Curtiss 0 (0 0 0 2 0)
de Havilland Canada 2 (1 4 1 3 4)
Dornier 0 (0 0 0 0 2)
(MDD) Douglas 2 (1 1 3 4 10)
Embraer 2 (0 2 0 1 3)
Fairchild 0 (1 1 0 0 0)
Fokker 1 (1 2 1 1 2)
GAF 0 (0 0 1 0 0)
Grumman 0 (1 0 0 0 0)
Hawker Siddeley 1 (0 1 0 0 1)
Ilyushin 2 (1 1 2 0 1)
Lisunov 1 (0 0 0 0 0)
Let 2 (3 4 4 1 2)
Lockheed 0 (1 1 0 1 2)
PZL Mielec 0 (0 0 1 0 0)
Saab 0 (0 0 0 1 0)
Shorts 0 (1 0 1 3 0)
Sud Aviation 0 (0 0 1 0 0)
Swearingen 0 (2 1 3 1 0)
Transall 0 (0 0 1 0 0)
Tupolev 0 (1 2 2 0 1)
Yakovlev 1 (0 0 1 1 2)
Yunshuji 0 (0 0 0 2 0)
Western built 18 (17 25 22 29 36)
(former) Eastern Block built 8 (8 12 12 9 9)
Total 26 (25 37 34 36 45)

Number of accidents per country [where the accident happened] 2004 (2003, 2002, 2001 figures in parentheses)

In 2004, just like the years before, the United States suffered the highest number of fatal airliner accidents: 4. Just one of these concerned a passenger flight.

Algeria 1 (1 0 0)
Angola 0 (0 0 1)
Argentina 0 (1 0 0)
Azerbaijan 1 (0 0 0)
Benin 0 (1 0 0)
Brazil 2 (0 2 0)
Canada 1 (1 0 1)
Central African Rep. 0 (0 1 0)
China 2 (0 1 0)
Colombia 1 (1 3 2)
Comoros 0 (0 1 0)
Congo (former Zaire) 0 (0 0 2)
Djibouti 0 (0 1 0)
East Timor 0 (1 0 0)
Egypt 1 (0 0 0)
Estonia 0 (1 0 1)
France (including overseas) 0 (1 0 1)
Gabon 1 (1 0 0)
Germany 0 (0 1* 0)
Guatemala 0 (0 0 1)
Guyana 0 (1 0 0)
Haiti 0 (1 0 0)
Indonesia 1 (1 2 2)
Iran 0 (0 2 1)
Italy 0 (0 0 1)
Kenya 1 (2 1 0)
Liberia 0 (0 1 0)
Luxembourg 0 (0 1 0)
Mexico 0 (0 1 1)
Morocco 0 (0 1 0)
Nepal 1 (0 2 0)
New Zealand 0 (1 0 0)
Nigeria 0 (0 2 1)
Papua New Guinea 1 (0 0 0)
Peru 0 (1 0 0)
Philippines 0 (0 1 0)
Russia 1 (1 2 3)
South Africa 0 (0 1 0)
South Korea 0 (0 1 0)
Spain 0 (0 2 2)
Sudan 3 (2 0 0)
Surinam 0 (0 0 1)
Switzerland 0 (0 0 1)
Taiwan 0 (0 1 0)
Thailand 0 (0 0 1)
Tunisia 0 (0 1 0)
Turkey 0 (2 0 0)
UK 0 (0 0 1)
United Arab Emirates 1 (0 0 0)
USA 4 (3 3 7)
Uzbekistan 1 (0 0 0)
Venezuela 1 (1 0 2)
Atlantic Ocean 1 (0 0 1)
Pacific Ocean 0 (0 1 0)
Total 26 (25 37 34)
*collision

Summarized per continent 2004 (2003, 2002, 2001, 2000 figures in parentheses)

In 2004 Africa was again the most unsafe continent. In total, 27% of all fatal airliner accidents happened in Africa, while Africa only accounts for approximately 3% of all world aircraft departures. The moving 10-year average trends show a decrease in the average number of fatal accidents for Europe, and North-, South-, and Central America over the past 6 to 7 years. Africa, on the other hand, shows an increase from a 10-year average of 5.1 accidents in 1993 to 7.7 accidents in 2004. The average number of accidents per year in Australasia has remained stable at approximately 1.4 since 1995.

Africa 7 (7 10 4 9)
Asia 7 (2 11 4 8)
Australia 1 (1 0 0 0)
Central America 1 (1 0 2 4)
Europe 1 (5 7 10 5)
North America 5 (4 4 9 9)
South America 4 (5 5 5 1)
Total 26 (25 37 34 36)

Flight nature

From a passenger's point of view, the year 2004 was the safest year in aviation since Word War II. The number of fatal passenger flight accidents was never this low (11). It's followed by a large distance by 2003 (14) and 1984/2002 with both 20 passenger flight crashes each. A breakdown by flight nature shows a continuous decrease in the number of scheduled passenger flight accidents over the last 5 years. On the other hand, the number of cargo plane accidents shows a marked increase. (2003, 2002, 2001, 2000, 1999 figures in parentheses)

Ambulance 0 (0 0 1 0 0)
Ferry/positioning 1 (2 5 0 1 3)
Firefighting 0 (1 2 0 1 0)
Freight 13 (7 9 5 9 16)
Non-scheduled passenger 1 (5 4 7 9 4)
Skydiving 0 (1 0 0 0 1)
Scheduled passenger 8 (8 12 13 14 19)
Training 0 (0 0 1 0 0)
Passenger *) 2 (1 4 3 0 1)
? 1 (0 1 4 2 0)
\- 0 (0 0 0 0 1)
Total 26 (25 37 34 36 45)

*unknown if these flights were scheduled or non-scheduled passenger flights.

Flight phase

Compared to the year before, 2004 showed an increase again in the number of approach and landing accidents, which is one of the four most pressing safety problems facing the aviation industry according to the Flight Safety Foundation. In 2004, they accounted for 46% of all accidents, compared to 32% in 2003, 54% in 2002, and 38% in 2001. (2003, 2002, 2001, 2000, 1999 figures in parentheses)

Standing 0 (0 0 1 0 0)
Takeoff 2 2 (1 3 3 2)
Initial climb 2 (4 1 2 4 2)
Enroute 8 (9 14 15* 13 21)
Maneuvering 0 (2 2 0 1 0)
Approach 9 (8 17 12 11 11)
Landing 3 (0 2 1 3 8)
Unknown 2 (0 0 0 1 1)
Total 26 (25 37 34 36 45)

*including 5 other occurrences (shoot down + 4 hijackings)

1999: 1 landing, 2 enroute accident shoot downs and criminal act

Investigate, Communicate, Educate: Are We Doing It?

Are investigators fooling themselves into believing that they are advocating safety communications? That the message is consistently passed to all of those who need to receive it? That they consistently target those entities who can learn from the investigations and who are in a position to fix the deficiency that caused the safety communication?

By Réal Levasseur (CP0060), Transportation Safety Board of Canada (TSB)

(This article was adapted, with permission, from the author's presentation entitled Investigate, Communicate, and Educate: Are We Doing All Three With The Same Energy? *presented at the ISASI 2004 seminar held in Australia's Gold Coast region Aug. 30 to Sept. 2, 2004. The full presentation is on the ISASI website at www.isasi.org. --Editor)*

An "association" is generally defined in dictionaries as the organizational outcome of the banding together of individual entities having common traits, interests, and purposes, and sharing a common objective to support their mutual interests. Thus the traditional roles for an association are advocacy—the act of speaking or writing in support of something—and using its group influence in order to attain this common interest, goal, or objective. This definition certainly seems to fit ISASI. Now that we have sorted out who we are, what are the goals of ISASI members? I will define for you the mandate of the Transportation Safety Board, and I am confident that this mandate will be fairly close to the goals of ISASI members. It is to advance transportation safety in the marine, pipeline, rail, and air modes of transportation by

- conducting independent investigations, including public inquiries when necessary, into selected transportation occurrences in order to make findings as to their causes and contributing factors;
- identifying safety deficiencies, as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- reporting publicly on its investigations and related findings.

***Réal Levasseur** is the chief of Air Investigation Operations for the TSB. A former fighter pilot with the RCAF and later the CAF, he retired from the military after having served for 30 years in various functions and positions of command, as a pilot, and in senior administrative positions. In his last military job, he held the position of chief accident investigator for the Directorate of Flight Safety within Canada's Department of National Defense. Réal joined the TSB in 1993, and has since been involved in various capacities in a number of Canadian and foreign civilian aircraft accidents.*

Investigation role

We [ISASI] are aviation professionals involved in aircraft accident investigation. Whether we may be also employed as pilots, engineers, technicians, or others, we like to think of ourselves as experts in our field. And why should we not feel this way? After all, we have received extensive training in basic and advanced investigation procedures, biohazards, interview and photography techniques, jet engine and propeller mechanics, crash site survey, team leadership and management, safety deficiency analysis, human factors, and a multitude of other assorted specialty courses.

We feel good about our capabilities. We can all recite the SHELL and Reason theories backwards. Anyone who has ever been involved in an accident investigation as investigator-in-charge, team member, accredited representative, observer, or in any other capacity believes that his/her efforts have helped advance safety. We identify safety deficiencies evidenced during the course of our work, and make recommendations to mitigate or eliminate those risks to the travelling air passenger.

The question is, or rather, the questions are How well are we advocating our safety communications? Is the message consistently passed to all of those who need to receive it? Do we consistently target those entities who can learn from our investigations and who are in a position to fix the deficiency that caused the safety communication? Are we fooling ourselves in believing this is so? We can investigate every transportation accident and derive exact conclusions and findings all we want, but if we do not properly pass the safety communication aimed at fixing the problem, we have wasted our money, time, and effort, and we also have missed the boat, to use a common expression.

Identification aspect

The most important aspect of an investigation is the identification of unsafe acts, unsafe conditions, and underlying factors that led to the incident or accident. This methodology will allow an investigator to validate safety deficiencies that will have also been identified through this process. A validated safety deficiency preamble and its concluding section must

- demonstrate that defenses were inadequate, missing, or failed.
- address the possibility of a recurrence.
- consider and analyze the severity of consequences.
- provide risk-control options (is improvement feasible?).
- result in safety communications aimed at mitigating or eliminating the identified risk by those responsible.

Naturally, each State investigation agency has to consider a number of factors in determining whether an incident or accident will be investigated. Although ICAO Annex 13, Chapter 5, Investigation, states that accidents *shall* be investigated and that serious incidents *should* be investigated, it is evident that we cannot do everything, as our resources are limited. Having said that, we should naturally concentrate on those occurrences where the safety payoff appears to be the best. This requires that we have a close initial look at each occurrence to determine the possible level of that safety communication payoff.

Through this article I hope to present measures, ideas, and solutions that may help us improve the results of our investigating efforts, that of saving lives, property, and environmental damage.

The challenge is that if we cannot "communicate" adequately, we will de facto fail to do the "educate" part of the 2004 ISASI seminar trilogy theme, Investigate, Communicate, Educate, as both go hand in hand. The result is that the safety message will not be passed, and recurrence under similar circumstances becomes simply a matter of time.

Although we may be excellent at investigating for causes and contributing factors, we have yet to consistently advocate our bread and butter: communication and education. As stated, we are very good at determining the who, what, and why of crumpled aluminum and rotating parts. Most major accidents include unsafe acts, conditions, or underlying factors where the risk was real and the defenses to prevent the mishap were less than adequate or nonexisting. Sometimes, however, we simply fail to properly communicate a validated safety deficiency to the right party—the one who can fix the problem. At other times, our reports do not explain clearly what the exact nature of the deficiency was, leading the recipient of the safety communication to disagree with our recommendations aimed at reducing this risk; as a result, nothing gets fixed. (How often have you heard the statement "We disagree with your risk analysis"?) On occasion, it becomes too difficult to fully develop a safety deficiency for a number of reasons (lack of factual evidence, difficult analysis, industry pressure, or other), and we just give up.

Recommendation advocacy

Finally, we do not advocate or push our product sufficiently. We write our recommendations and then let others take action as they see fit, hoping they will do the right thing. We consider our work done once the investigation report has gone out the door. If those others do not take appropriate action, we see this as *their* problem, because we told them about it... right? On many occasions, we have not been very good at following up and evaluating government and industry responses to recommendations. Specifically, we have failed to consistently track their proposed actions in response to our recommendations, and we have not verified the timely implementation of those proposed actions. Our reports and proposed safety action often do not reach each of those who need to be apprised of this information. Sometimes they don't get the safety message in time; at other times, they simply do not get it at all and as a result we later observe a repeat of an earlier accident.

Our overall past performance in passing the communicate and educate safety message has certainly had its ups and downs. The jury is still out, I believe, whether the ups are winning the battle. Through this article I hope to present measures, ideas, and solutions that may help us improve the results of our investigating efforts, that of saving lives, property, and environmental damage. To set the scene, here are few examples highlighting the difficulties to get safety deficiencies corrected.

Examples

On Dec. 16, 1997, a Bombardier RJ100 crashed while conducting an approach to a Canadian airport. The reported aerodrome weather at the time of the accident was vertical visibility 100 feet obscured, horizontal visibility one-eighth of a mile in fog, and runway visual range 1,200 feet. After the autopilot was disengaged at 165 feet above ground, the aircraft deviated from the desired flightpath. The aircraft crashed shortly after the captain ordered a go-around because he was not sure that a safe landing could be made on the runway remaining.

Canadian regulations permit Category I approaches to be flown in visibilities lower than would be permitted in most other countries (including the United States), and the regulations are not consistent with what is recommended in ICAO international standards and recommended practices. To compensate for the risk associated with landing an aircraft in conditions of low ceiling and visibility, extra aids and defenses should be in place. Therefore, to reduce the risk of accidents in poor weather during the approach and landing phases of flight, the TSB recommended that

"The Department of Transport reassess Category I approach and landing criteria (realigning weather minima with operating requirements) to ensure a level of safety consistent with Category II criteria."—(TSB Recommendation A99-05)

On Aug. 12, 1999, a Raytheon Beech 1900 crashed while on approach to a Canadian airport at night. At the time of the approach, the reported ceiling and visibility were well below the minima published on the approach chart. The crew descended the aircraft well below safe minimum altitude while in instrument meteorological conditions. Throughout the approach, even at 100 feet above ground level (agl), the captain asked the pilot flying to continue the descent without having established any visual contact with the runway environment.

The accident report concluded that the issue of additional regulatory restrictions for instrument approaches in poor weather has been discussed in Canada for several years because of the number of accidents that occur during the approach and landing phase. Indeed, from January 1994 to December 2001, the Board investigated 24 such accidents where low visibilities and/or ceilings likely contributed to the accident. Consequently, controlled-flight-into-terrain accidents on approach that result in loss of life and damage to property have continued to occur and will likely continue to occur. The TSB, therefore, recommended that

"The Department of Transport expedite the approach ban regulations prohibiting pilots from conducting approaches in visibility conditions that are not adequate for the approach to be conducted safely."—(TSB Recommendation A02-01)

The TSB further recommended that "The Department of Transport take immediate action to implement regulations restricting pilots from conducting approaches where the ceiling does not provide an adequate safety margin for the approach or landing."—(TSB Recommendation A02-02)

On April 13, 1999, a Cessna 335 was on an instrument flight with two pilots and two passengers on board. After checking the prevailing weather conditions at the destination, the pilot decided to make a back course approach on Runway 29 at the Gaspé, Québec, Canada, aerodrome. The pilot reported by radio at 2 miles on final approach.

Bombardier RJ100 crash.

This was the last radio contact with the aircraft. A search team travelling along a dirt road bordering the runway found the aircraft. A very intense fire consumed the aircraft. All four occupants received fatal injuries. The reported weather at the time of the accident was as follows: visibility one-quarter mile in heavy snow and vertical visibility 300 feet. No aviation regulation in Canada prevents pilots from making instrument flight rules (IFR) approaches where weather conditions are below the approach minima (ceiling and visibility) and no RVR is available at the airport

Wait, there is more. On Feb. 25, 2004, a Boeing 737 aircraft landed beside the runway in the wee hours of the morning. You guessed it. The weather was not cooperating once again. The reported runway visual range was 1,200. The crew lost visual references with the ground after committing to the landing. Fortunately, no one was hurt. Close, but no cigar as they say.

On April 25, 2004, another Beechcraft C-100 overran the end of a runway and crashed when it landed near the departure end in poor visibility. I could mention many more commercial operations approach and landing accidents related to low ceilings and visibility investigated by the TSB in the last 10 years.

What happened to the above recommendations? In September 1999, Transport Canada had initiated action to implement new approach ban regulations aimed at reducing the likelihood of accidents during instrument approaches in low-visibility conditions. But this process is still ongoing. Until these regulations are promulgated, there will continue to be inadequate defenses against the risks associated with pilots descending below the decision height or minimum-descent altitude in an attempt to land in visibility conditions that are unsafe. We will continue to investigate this type of accident until some day, large amounts of blood are spilled under these conditions. The deficiency will then be vigorously addressed, but it will of course have been too late. Why is the message not getting through?

Maintenance issues

Let's look at two cases involving maintenance issues. On June 14, 1999, a Beech A-100 aircraft crashed near the airport shortly after takeoff. After getting airborne, the aircraft was observed to immediately pitch up to approximately a 70-degree angle. It then appeared to stall at an altitude estimated to be between 500-700 feet agl. The nose then fell through the horizon to a pronounced nose-down attitude. As the airspeed built up, the aircraft began to recover from the excessive nose-down attitude. As the aircraft was beginning to enter into a second roller-coaster sequence, it contacted the ground and crashed. The wreckage trail, consisting of the underbelly baggage pod and its contents, all landing gear, and the left propeller assembly, covered a distance of 491 feet. The remainder of the aircraft came to rest essentially in one piece after it had crossed over a railroad bed and track. A small fuel-fed fire from the punctured left wing ensued a few minutes after the occupants exited the aircraft, but the fire was rapidly extinguished by the airport firefighting services. Miraculously, no one aboard was seriously injured.

The investigation quickly determined that the primary and alternate trim "H" bracket attaching the aircraft's stabilizer to the airframe had been improperly reconnected during weekend maintenance performed prior to the flight. After the occurrence, investigators found that the top of the actuators was not attached to the airframe. The two bolts did not pass through the actuator holes when reinstalled, but only through the attachment holes in the airframe. When the bolts were tightened during installation, they squeezed the ends of the actuators to the attachment points on the airframe. The inspection was carried out superficially without close inspection from inside the tail cone or using the tools, such as a mirror, that would be standard for this type of inspection. The accident report mentioned the difficulty in visually verifying that the bolts were inserted properly in the airframe channel, and suggested that the aircraft maintenance manual directives concerning this task could be enhanced.

Then, it happened again! On April 23, 2003, a Beech 99A was on a scheduled flight from Saskatoon to Prince Albert, Saskatchewan, with a crew of two and four passengers on board. This was the 12th flight following major inspection and repair activity and the aircraft had flown approximately 7 hours since completion of the work. Shortly after the flaps were selected for approach, a loud bang emanated from somewhere in the tail and the aircraft immediately started to pitch up. The crew applied full forward elevator and reduced power. The airspeed slowed and from a near-vertical attitude, the aircraft rolled left then pitched steeply nose down. The crew applied full-up elevator and full engine power to recover from the dive. The nose of the aircraft came up and the crew extended the landing gear just prior to a high-speed touchdown on rolling agricultural fields. On contact with the ground, all three landing gear and the belly baggage pod were torn from the aircraft. The aircraft slid to rest approximately one-half mile from the initial ground contact point. The crew and passengers exited the aircraft through the main cabin door. Injuries incurred were not life threatening.

Post-accident inspection revealed that the stabilizer trim actuator had detached from the fuselage structure allowing the stabilizer to move freely under the influence of air loads. During installation, the two bolts had been installed behind the actuator mounting lugs, trapping the lugs between the shanks of the bolts and rivets in the airframe structure. Sounds very much like the other one? You bet! The findings of this report as to cause and contributing factors were generally the same as those of the first one. An interesting finding as to risk read as follows: "The nature of the installation presents a risk that qualified persons may inadvertently install Beech 99 and Beech 100 horizontal stabilizer trim actuators incorrectly. There are no published warnings to advise installers that there is a potential to install the actuator incorrectly."

Collective TSB actions

On May 2, 2003, 10 days after the accident, the TSB issued an occurrence bulletin detailing the factual information relative to this occurrence and the Beech King Air 100 occurrence of June 1999. On June 20, 2003, the TSB forwarded a safety advisory regarding the facts of this occurrence to Transport Canada for potential safety action. Transport Canada produced a Service Difficulty Alert (AL-2003-07, dated July 17, 2003) based on the TSB occurrence bulletin, advising of the occurrence and indicating that the installation procedures in the maintenance manual were being reassessed. Transport Canada contacted the U.S. Federal Aviation Administration, requesting its assistance and that of the aircraft manufacturer, suggesting issuance of a service letter and incorporation of warnings in the appropriate aircraft maintenance manuals. Raytheon Aircraft issued King Air communiqué No. 2003-03 to alert appropriate operators and maintenance personnel of the possibility of incorrect installation of the actuators.

Has the message now been passed to all those who need to receive it? I sincerely hope so. Will all maintenance personnel working on those types of aircraft heed the message? I simply don't know. One thing is evident: if AMEs do not look at their maintenance manual when performing this function, my guess is that it will happen again.

How come the first lesson was not learned? Was it because our safety message was not strong enough in the first report? Was it ignored? Was it not received by all operators who have this type of trim bracket arrangement? Was it simply forgotten after a year? What could we/should we have done to ensure this did not happen again? We sometimes say that there are seldom new accidents, just old accidents revisited. For your sake and my sake, I hope we don't really mean this.

Communications aspects

Let's now look at the communications aspect. There are various methods by which each State's investigation agencies communicate safety deficiencies. These can range from the very informal verbal communications between the investigator-in-charge (IIC) of an incident or accident and the parties involved, all the way to the formal recommendations issued with a final report. Between these two extremes, we find initial reports, interim reports, factual reports, 60-day reports, occurrence bulletins, information and advisory letters, Board concerns, et j'en passe. All of those can

Raytheon Beech 1900D accident.

and often do convey a safety message that the intended recipient(s) should catch, understand, and act upon.

In Canada, the only safety action that requires a formal response is that expressed in the form of a Board recommendation to the Minister of Transport. All other interested parties, such as operators, Nav Canada, and other organizations need not respond or comment on any TSB safety communications. Finally, each State investigation agency has its own standards and processes as to how a safety action message should be drafted. Sometimes, States put the emphasis on defining the safety deficiency in the text of their recommendations and leave the nuts-and-bolts aspect of fixing the problem to those in the best position to do so. At other times, they are much more specific in the wording of their recommendations concerning the actions that need to be undertaken. It would be nice to have a recognized method or standard of accomplishing this, but are we dreaming in color?

Practices differ between State investigation agencies concerning safety actions directed at another State. The TSB has no set policy in this regard, and I suspect that other States may be in a similar situation. In some cases, safety action communications are sent directly to the foreign State's regulatory authorities. In other cases, recommendations are sent through the State's accident investigation authority, such as the NTSB, the ATSB, and the AAIB. Because the TSB has no set policy, our Board uses a mix of the two methods. I should point out that foreign regulatory authorities are not required to respond to safety communications issued by another State, but that they usually do. A State accident investigation authority can also put pressure on its own regulatory agency, manufactures, and operators to respond; nevertheless, the State issuing the safety communication may not get adequate feedback, due to this lack of an internationally recognized policy in this respect.

When it comes to operators, a formal response on their part to a State recommendation or other safety action proposal is, of course, not mandatory. Operators can take action to reduce the risk based on the safety communication, or they can simply ignore it. An operator can also agree to take action to mitigate a validated risk or deficiency and subsequently do nothing about it. Some of the determining factors are company set up, finances, attitude, and the importance attached to maintaining a healthy safety culture at all levels of the company. Furthermore, communications passed to an operator do not always simultaneously get transmitted to all other operators who need to receive the communication, especially when the deficiency has ramifications over more than one continent. Finally, States are not well equipped to monitor or track safety action taken by their own operators in response to a recommendation issued by another State. For these reasons, monitoring safety action taken by operators can be, and regularly is, a hit-and-miss affair.

Manufacturers of aeronautic products are also not required to respond formally to safety action emitted directly to them by a foreign State either, but they generally do. It is important for manufacturers to substantiate on paper the reason or reasons they may disagree with a given safety communication. If they agree with it, they must indicate the actions they will take or intend to take to mitigate or eliminate the safety risk. When the risk and its consequences are judged unacceptable, State regulatory authorities will normally issue an airworthiness directive directly to manufacturers and operators.

On issues where it can be argued (truthfully or not) that the risk is less than presented, manufacturers may choose to issue a service bulletin to operators and owners of the concerned aircraft, equipment, or part. To do nothing might be foolish, but at the same time, the manufacturer has to be concerned about the legal implications of admitting a deficiency in his product, especially if said product was found to have been at cause in previous occurrence(s). For that reason, manufacturers sometimes object to issuing a particular service bulletin as this action may imply some degree of responsibility for previously recorded or investigated events. Finally, the difficulty that investigation authorities have with service bulletins is, of course, the fact that they have no mandatory compliance, even when the manufacturer-recommended action has a "mandatory" status or a required completion deadline based on a given date or time in service of the part. Operators may choose to disregard a service bulletin, and some do.

Monitoring responses

Let's now look at how we actually monitor those responses we do receive, and what we do with these. Most investigation authorities such as the TSB have no power to mandate or require action to mitigate or eliminate the risk specified in its safety communications issued following investigation. The implementation of air regulations is the responsibility of the State regulatory authority, and there is an excellent reason for that. This method allows investigation authorities to maintain a complete independence from the regulatory arm of a government. On the other hand, that same reason distresses us as investigators when we see recurring accidents, such as those described earlier, year after year because the risk-control options evidenced in our safety action recommendations are not being implemented.

In Canada, the only safety action that requires a formal response is that expressed in the form of a Board recommendation to the Minister of Transport. All other interested parties, such as operators, Nav Canada, and other organizations need not respond or comment on any TSB safety communications.

At the TSB, one of my responsibilities is to track all formal responses to safety action, including those responses emitted by foreign States, operators, and manufacturers. Each response to a recommendation is initially sent to the IIC, who then provides my office with his assessment in one of the following categories: fully satisfactory, satisfactory intent, satisfactory in part, or unsatisfactory. The assessment is then reviewed at the head office against the standard and then forwarded to the Board. The assessments are reviewed on an annual basis to ascertain progress on mitigating risk evidenced in safety communication. Currently, in Canada, the assessment category given is not passed back to those who provided the response and, therefore, the feedback stops at that point. As a result, there is no impetus for the action addressee to show due haste in addressing the problem. The risk may, therefore, remain unchanged.

While addressing the tracking and assessment of responses to safety communications, let's look at the type of response we all too often receive. Life would be great if each response began with a statement of agreement with the recommendation, the actions that will be taken to reduce or eliminate the risk, and the milestones to accomplish the task clearly shown. Unfortunately, that is not what we get. How can we properly address and assess a response that contains mostly explanations rather than actions, and where no implementation timeframe is given? I wish I knew how to answer this question, because if there ever was a million-dollar question, this is it. This should not, however, stop us from searching for the answer.

Communication realm

Sadly, our safety communications do not always convincingly demonstrate the residual risk, the probability of recurrence, and the severity of consequence (weak evidence or wording) to the interested party. This results in a weak impact of the safety message we are trying to convey, and, accordingly, it receives an inappropriate level of attention and response. As an example, parties to an investigation are not always involved in the full analysis process that allows for better understanding of the safety issues involved. Some States may feel that they are losing a degree of independence in doing so. However, I believe we can retain our independence while ensuring involved parties understand the thought process behind each safety issue being analyzed. This method makes it easier to reach a consensus on a deficiency that needs to be addressed.

Further, our recommendations are sometimes directed at the wrong addressee, that is, they are not communicated to those requiring the information. Because we do not have international standards related to safety communications to a foreign State, we sometimes miss the mark. As stated earlier, action taken is often not adequately tracked and the response assessments are not made public by all investigating authorities. Those entities responsible for effecting change are often not challenged when their response is judged inadequate. Finally, the response often does not provide mitigating action milestones. These are important issues that organizations such as [ISASI] or ICAO may wish to pursue further in order to advance safety.

Having said that, have our investigative efforts produced results? Let's take a look at our past performance and take a shot at the future.

It is a fact that deadly mistakes by commercial and airline pilots have decreased dramatically over the last decade. In other words, the old "pilot error" findings have been on a steady downward slide. That is a good thing, as Martha Stewart would say. Year 2003 was in fact one of the best in commercial air transport history. Was that a fluke? I don't think so. We will never know how many accidents we have prevented due to our concerted efforts, but the numbers do not lie. We are indeed making progress with the "beast," but we must not rest.

CFIT continues to be one of the main causes of accidents. The enhanced ground proximity warning system (EGPWS) is reported to be a major player in helping to reduce CFIT accidents. Indeed, no aircraft equipped with this updated system has been involved in a CFIT accident to date.

That's the good news. I wish everything else was this rosy, but it is not. Fatal accidents caused by maintenance errors are seen to be on the increase. There are claims that in 10 years there will be one major accident per week due to air traffic increase, unless the accident rate is reduced. The risk of mid-air accidents is also real, as evidenced by the recent mid-air collision in Germany. RVSM rules will make navigation and altitude-bust errors yet more critical. ETOPs and over-the-pole flights will increase, with the associated risk of someday having to investigate an accident around the polar cap. We can also expect there will continue to be major accidents over water or at sea, like TWA 800, SWR 111, and the more recent Alaska Airlines and Flash Air flights.

Making things better

So, what are we doing to make things better? Flight Operational Quality Assurance (FOQA) is coming on line in some States. FOQA is seen as a great tool for tracking and investigating incidents before they become accidents. Quick access recorders (QARs) offer the possibility of increased FDR data gathering capabilities. The technology is already there. Manufacturers and their engineers need only invest a little more time, money, and effort into developing a hardened QAR, and the capability to extricate the facts of an accident will increase exponentially.

Any accident investigator can see the advantages of having additional data. An accident sequence sometimes begins well over the half-hour that older CVRs capture. Two-hour CVRs are being installed in new aircraft, and some older ones are being retrofitted with the improved boxes. There are still some hurdles to clear, but the possibility of having video recorders in aircraft cockpits in the future is beginning to take hold, as the advantages of this technology are real and are being recognized.

A large number of aircraft systems now capture information into non-volatile memory chips that can reveal important information to help determine the cause of an accident. Finally, many investigation authorities have, or are developing, a list of safety issues that they are interested in. It would be a good idea for us to exchange notes on those safety issues we each are interested in pursuing.

Our challenge is clear: each safety deficiency that we identify and validate during the course of our investigations must be addressed.

The educate challenge

The challenge to educate is real. Aviation safety does not improve by quantum leaps over short periods. Rather, it goes through a series of up and down curves, as we fix old deficiencies while new ones pop up.

Accident investigators will have to make every effort to ensure that safety communications reach all those affected by the risk. We must learn to think globally instead of locally. We must, therefore, standardize our approach to safety communications—that is develop coherent related internationally recognized policies and standards. FOQA data will be of limited use if gathered threshold information is not investigated properly, or if the results are not passed to others who can learn from other's mistakes. Investigating authorities must become more active in advocating safety action, and those responsible for effecting changes to improve safety must show diligence in mandating those changes.

Our challenge is clear: each safety deficiency that we identify and validate during the course of our investigations must be addressed. We must write clear, convincing safety communications, and it is imperative that these be targeted at the appropriate audience. If we fail to do this, our message will not get the attention it deserves and others will not learn about these identified risks.

Finally, unless we as investigators make vigorous efforts to track responses to communications and critically assess action taken as a result of these communications, those risks will remain. The tragedy will be that we will know that we could have done more to prevent a catastrophic recurrence of a serious accident, but did not. We will have to live with that knowledge. The alternative, advocating safety at all levels, requires more work and dedication on our part, but is much more rewarding in the end.

As I noted earlier, the traditional role of organizations is advocacy. So let's do some hard thinking among ourselves as to how we can best advocate out there! Surely, we can improve our track record, but it will require constant effort, innovation, and dedication toward the aim.

Any bright ideas out there? ◆

Latent Failures in the Hangar

To uncover latent failures in aviation maintenance, accident investigators must recognize the invisible cognitive demands and pressures that confront maintenance personnel.

By Dr. Alan Hobbs (MO3425), SJSU/NASA-Ames Research Center, U.S.A.

(This article was adapted, with permission, from the author's presentation entitled Latent Failures in the Hangar: Uncovering Organizational Deficiencies in Maintenance Operations *presented at the ISASI 2004 seminar held in Australia's Gold Coast region Aug. 30 to Sept. 2, 2004. The full presentation showing cited references is on the ISASI website at www.isasi.org.—Editor)*

Accident statistics for the worldwide commercial jet transport industry show maintenance as the "primary cause factor" in a relatively low 4% of hull-loss accidents, compared with flight crew actions that are implicated as a "primary cause factor" in more than 60% of accidents. Yet such statistics may understate the significance of maintenance as a contributing factor in accidents. When safety issues are presented alongside the fatalities that have resulted from them on worldwide airline operations, deficient maintenance and inspection emerges as the second-most-serious safety threat after controlled flight into terrain. According to former NTSB Board member John Goglia, maintenance has been implicated in 7 of 14 recent U.S. airline accidents.

While it may be tempting to consider that the lessons learned about human performance in other areas of aviation will translate readily to maintenance, some of the challenges facing maintenance personnel are unique. Maintenance technicians work in an environment that is more hazardous than all but a few other jobs in the labor force. The work may be carried out at heights, in confined spaces, in numbing cold, or sweltering heat. Hangars, like hospitals, can be dangerous places. We know from medicine that iatrogenic injury (unwanted consequences of treatment) can be a significant threat to patient health. In maintenance, as in surgery, instruments are occasionally left behind, problems are sometimes misdiagnosed, and operations are occasionally performed on the wrong part of the "patient." Aircraft and human patients also have another common feature in that many systems are not designed for easy access or maintainability.

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To understand maintenance deficiencies, we need to understand the nature of the work performed by maintenance personnel, and the potential for error that exists in maintenance operations. It is relatively easy to describe the work of maintenance personnel at a physical level: They inspect systems; remove, repair, and install components; and deal with documentation. Yet, like virtually every human in the aviation system, maintenance personnel are not employed merely to provide muscle power. They are needed to process information, sometimes in ways that are not immediately apparent. In order to uncover latent failures in aviation maintenance, we must recognize the invisible cognitive demands and pressures that confront maintenance personnel.

In general, line maintenance tasks progress through a series of stages, much like the stages of a flight. The information-processing demands change as the job progresses. The preparation stage involves interpreting documentation and gathering tools and equipment. The work area must then be accessed, most likely by opening panels or removing components. After core activities such as inspection, diagnosis, and repair, the task concludes with documentation and housekeeping, or cleanup tasks.

The author conducted an analysis of the activities of 25 aircraft engineers at two international airlines. At 15-minute intervals, participants were asked to describe the nature of the task they were performing at that moment, according to whether it was routine, involved familiar problems, or involved unfamiliar problems. A total of 666 observations were made of line maintenance activities. The analysis indicated that the preparation stage was not only the most time-consuming task stage, but was also a stage at which personnel must overcome challenges and solve problems (see Figure 1). Between 15 and 20% of their time was spent performing work packages they had never performed before. Diagnosis and functional testing also presented significant problem-solving demands and involved relatively little routine task performance.

The nature of maintenance error

In recent years, analyses of databases of maintenance-related incidents and accidents have revealed some of the more common types of maintenance quality lapses.

In 1992, the U.K. CAA identified the major varieties of maintenance error as incorrect installation of components, the installation of wrong parts, electrical wiring discrepancies (including cross-connections), and material such as tools left in the aircraft. In a recent review of more than 3,000 maintenance error reports, as noted in a 2003 paper by W.L. Rankin and S.L. Sogg, parts not installed, incomplete installation, wrong locations, and cross-connections were the most common error types. The most common airworthiness incidents reported in a survey of Australian licensed aircraft maintenance engineers (LAMEs) were incomplete instal-

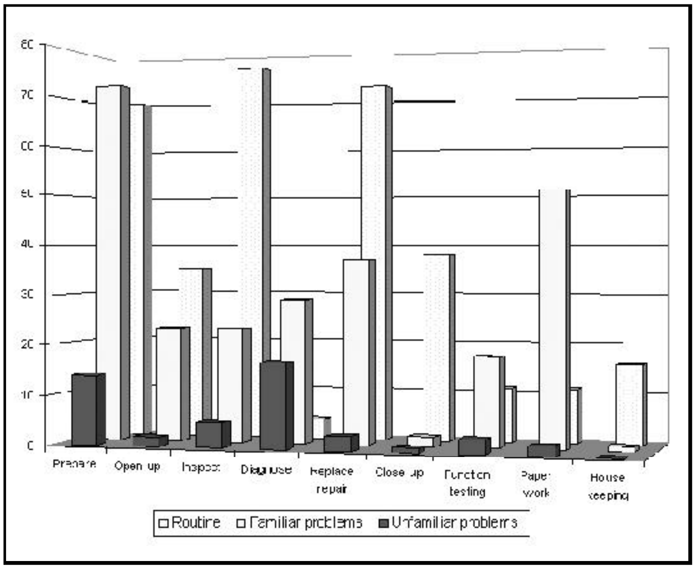

Figure 1. Cognitive demands and job stage in line maintenance (N=25). Vertical scale represents number of observations.

lations, incorrect assembly or location, vehicles or equipment contacting aircraft, material left in aircraft, wrong part, and part not installed.

Applying human-error models to maintenance discrepancies reveals that underlying these events are a limited range of cognitive error forms. More than 50% of the maintenance errors reported in the Australian survey could be placed in one of three categories: memory failures, rule violations, or knowledge-based errors.

Memory failures

The most common cognitive failures in maintenance incidents are failures of memory. Rather than forgetting something about the past, the engineer forgets to perform an action that he had intended to perform at some time in the future. Examples are forgetting to replace an oil cap or remove a tool. Memory for intentions, also known as prospective memory, does not necessarily correlate with performance on standard measures of memory, according to G. Cohen in *Memory in the Real World*. Prospective memory also appears to show a marked decrease with age, a finding that may have implications for older maintenance personnel.

Rule violations

Common rule violations include not referring to approved maintenance documentation, abbreviating procedures, or referring to informal sources of information such as personal "black books" of technical data.

In a study of the everyday job performance of European aircraft mechanics ("Safety Management Systems and Safety Culture in Aircraft Maintenance Organizations"), N. McDonald and his colleagues found that 34% acknowledged that their most recent task was performed in a manner that contravened formal procedures. McDonald et al. refer to the "double standard of task performance" that confronts maintenance personnel. On the one hand, they are expected to comply with a vast array of requirements and procedures, while also completing tasks quickly and efficiently. The rate at which mechanics report such violations is a predictor of involvement in airworthiness incidents. Violations may also set the scene for an accident by increasing the probability of error, or by reducing the margin of safety should an error occur. For example, the omission of a functional check at the completion of maintenance work may not in itself lead to a problem, but could permit an earlier lapse to go undetected.

The survey of Australian airline maintenance personnel indicated that certain critical rule workarounds occur with sufficient regularity to cause concern. More than 30% of LAMEs acknowledged that in the previous 12 months they had decided not to perform a functional check or engine run. More than 30% reported that they had signed off a task before it was completed, and more than 90% reported having done a task without the correct tools or equipment. These procedural non-compliances tend to be more common in line maintenance than in base maintenance, possibly reflecting more acute time pressures.

Knowledge-based errors

Jens Rasmussen introduced the term "knowledge-based error" to refer to mistakes arising from either failed problem-solving or a lack of system knowledge. Such mistakes are particularly likely when persons are feeling their way through an unfamiliar task by trial and error. Most maintenance engineers have had the experience of being unsure that they were performing a task correctly. In particular, ambiguities encountered during the preparation stage of maintenance tasks may set the scene for errors that will emerge later in the task.

Errors and violations

As Jim Reason has made clear, errors and violations such as those described above may be symptomatic of latent failures in the organization. As such, they may call for responses at the level of systems rather than interventions directed at individuals. System issues in aircraft maintenance can be divided into two broad classes.

The first class of system issues comprises well-recognized systemic threats to maintenance quality. These issues have been so thoroughly identified that they can hardly be called "latent failures." They include broad issues such as time pressure, inadequate equipment, poor documentation, night shifts, and shift hand-overs. In his keynote address to the 2001 Human Factors in Maintenance Symposium, Ken Smart listed a set of factors that can increase the chance of error, including supervisors performing hands-on work, interruptions, and a "can do" culture. Of these factors, time pressure appears to be the most prevalent in maintenance occurrences. Time pressure was referred to in 23% of maintenance incidents reported in the Australian LAME survey. Time pressure was also identified as the most common contributing factor in Aviation Safety Reporting System (ASRS) maintenance reports received by NASA. This does not necessarily indicate that maintenance workers are constantly under time pressure. However, incident reports indicate that time constraints can induce some maintainers to deviate from procedures. Although these system issues are recognized as threats to work quality, the extent to which they are present will vary from workplace to workplace. Evaluating the threat presented by each factor is an important step toward managing maintenance-related risks.

The second class of system issues can be more truly referred to as latent failures. These tend to be task-specific risks that can remain dormant for a considerable time. There are numerous main-

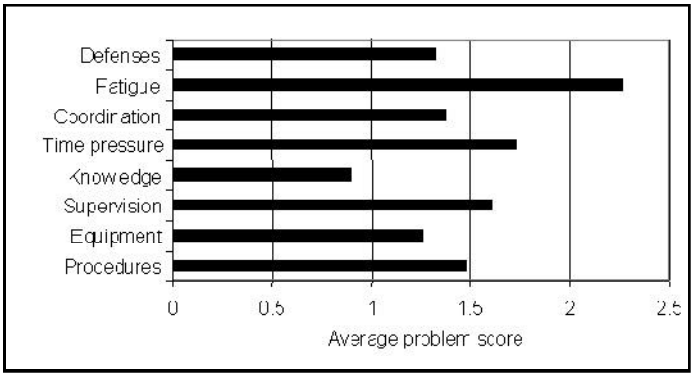

Figure 2. Example of a maintenance environment profile for a line maintenance organization.

tenance tasks that are associated with a recurring error, sometimes due to difficult access, ambiguous procedures, or other traps. Two well-known examples are static lines to an air data computer on a twin-engine jet aircraft that must be disconnected to reach another component, with the result that the lines are sometimes not reconnected, and wheel spacers that routinely stick to a removed wheel, resulting in the new wheel being installed without the spacer.

Barriers to uncovering maintenance issues

Despite the extensive documentation that accompanies maintenance, the activities of maintainers may be less visible to management than the work of pilots. A major challenge is to increase the visibility and openness of maintenance operations.

Time

While some maintenance errors have consequences as soon as the aircraft returns to service, in other cases months or years may pass before a maintenance error has any effect on operations. The world's worst single aircraft disaster resulted from an improper repair on the rear pressure bulkhead of a short-range B-747. The aircraft flew for 7 years after the repairs were accomplished before the bulkhead eventually failed, according to M. Job, in *Air Disaster (Vol. 2)*.

The passage of time between an error and its discovery can make it difficult to reconstruct events. Despite the extensive documentation of maintenance work, it is not always possible to determine the actions or even the individuals involved in a maintenance irregularity. In the words of one manager, "Most maintenance issues are deep and latent; some items are more than two-and-a-half years old when discovered and the mechanics have forgotten what happened."

Blame culture

The culture of maintenance has tended to discourage communication about maintenance incidents. This is because the response to errors is frequently punitive. At some companies, common errors such as leaving oil filler caps unsecured will result in several days without pay, or even instant dismissal. It is hardly surprising that many minor maintenance incidents are never officially reported. When Australian maintenance engineers were surveyed in 1998, more than 60% reported having corrected an error made by another engineer without documenting their action.

Outsourcing

The trend toward outsourcing places another potential barrier in the way of open disclosure of incident information. Some major airlines in the U.S. are now outsourcing up to 80% of their maintenance work. Third-party maintenance organizations may be reluctant to draw attention to minor incidents for fear of jeopardizing contract renewals.

Recent progress

In recent years, significant progress has been made in addressing the "not-so-latent" failures in maintenance operations. Several regulatory authorities now require maintenance error management systems that include human factors training for maintenance personnel and non-punitive reporting systems. For example, the U.K. Civil Aviation Authority (CAA) has released Notice 71 that encourages operators to introduce maintenance error management programs. A central part of such a program is a reporting system that allows people to report maintenance occurrences without fear of punishment.

The CAA states that "unpremeditated or inadvertent lapses" should not incur any punitive action. In the U.S., maintenance Aviation Safety Action Programs (ASAP) are being introduced, enabling maintainers to report inadvertent regulatory violations without fear of retribution. The success of such programs will depend on recognizing the spectrum of unsafe acts in maintenance, encompassing errors, violations, negligence, and recklessness, and defining in advance the types of actions that can be reported without fear of punishment. Establishing a clear policy on blame and responsibility should be a high priority for companies and regulators alike.

Investigation approaches

Structured investigation approaches are increasingly being introduced within maintenance. Systems include the Aircraft Dispatch and Maintenance Safety (ADAMS) investigation framework and Human Factors Analysis and Classification System—Maintenance Extension (HFACS-ME). The oldest and most widely known system is Boeing's Maintenance Error Decision Aid (MEDA), now used by approximately 50 airlines worldwide. MEDA presents a comprehensive list of error descriptions and then guides the investigator in identifying the contributing factors that led to the error.

Monitoring organizational conditions

In recent years, several proactive systems have been developed to measure safety culture in maintenance organizations. These include the Maintenance Climate Assessment Survey (MCAS), Maintenance Resource Management Technical Operations Questionnaire (MRM-TOQ), Managing Engineering Safety Health (MESH), and the Maintenance Environment Questionnaire (MEQ). The MEQ was developed by the author and is based on an earlier checklist administered to more than 1,200 maintenance engineers. The MEQ was designed to evaluate the level of error-provoking conditions in maintenance workplaces. The MEQ evaluates the following seven error-provoking conditions: procedures, equipment, supervision, knowledge, time pressure, coordination, and fatigue. In addition, the questionnaire contains items addressing maintenance defenses, or "safety nets," in the system. The eight factor scores are the main output of the survey. Once the question-
(continued on page 30)

Full-Flight Simulators and Accident Investigation

The use of flight simulation in accident investigation should be approached with care, acknowledging the fact that simulators have limitations.

By Robin Tydeman, Air Accidents Investigation Branch, U.K.

(This article was adapted, with permission, from the author's presentation entitled The Use of Full-Flight Simulators for Accident Investigation *presented at the ISASI 2004 seminar held in Australia's Gold Coast region Aug. 30 to Sept. 2, 2004. The full presentation is on the ISASI website at www.isasi.org.—Editor)*

Flight simulation has become an indispensable tool for training within aviation. In little more than 50 years, it has established a reputation for high levels of fidelity and the ability to provide an environment in which the effective training of aircrews can be conducted economically and safely. Flight simulation has also proven itself to be invaluable to the aircraft accident investigator. However, with the onset of digitally controlled simulators and compelling visual systems, it is easy to become beguiled by the supposed "fidelity." Any dependency on simulation will invite legitimate questions about the validity of any subsequent conclusions, and may cast doubts on the technical veracity of the investigation as a whole. I suggest that the use of flight simulation in accident investigation should be approached with care, acknowledging the fact that simulators have limitations.

The traditional use of flight simulators in accident investigation is to use the digital data from the flight data recorder (FDR) to program the simulator, usually a fixed-base engineering simulator, which will then replicate the flight of the aircraft. Data from the air traffic control radar, TCAS units, and the cockpit voice recorder can also be incorporated. Then, surely, the investigator has the complete picture! But how accurately does the simulator represent the aircraft and the ground and air environment in which it operates? While many flight simulators have a debrief facility that allows simulator data to be replayed for training purposes, a full-flight simulator was simply not designed to accept data from the FDR; errors, particularly with systems integration, will occur. A malfunction of an aircraft system is often the precursor to an accident investigation; but how accurately are these malfunctions presented in the flight simulator? Furthermore, since pilots involved in accidents usually exhibit the symptoms of a high workload, how can the simulator affect our understanding of the workload experienced by the pilot dealing with a problem? To answer these questions, and to identify those areas where the simulation can be expected to represent accurately the aircraft in flight and on the ground, let's consider the development of full-flight simulators, the regulatory framework within which they operate, and the problems of data acquisition for malfunctions.

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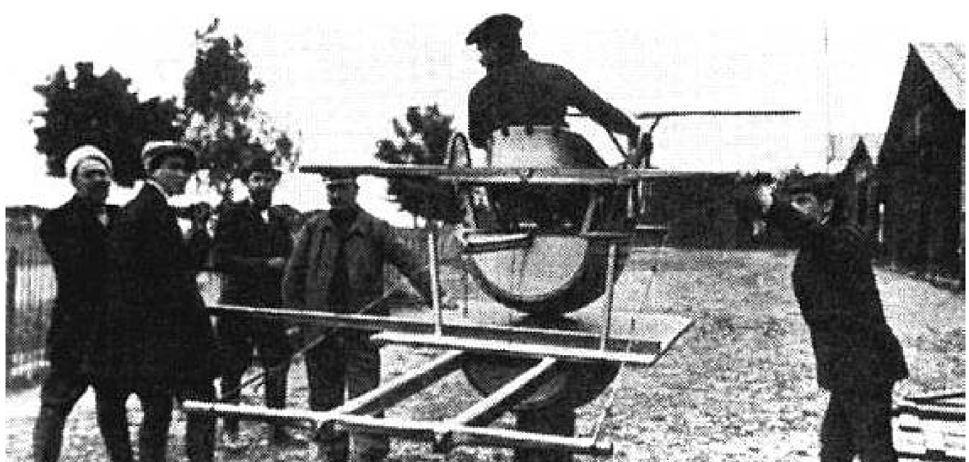
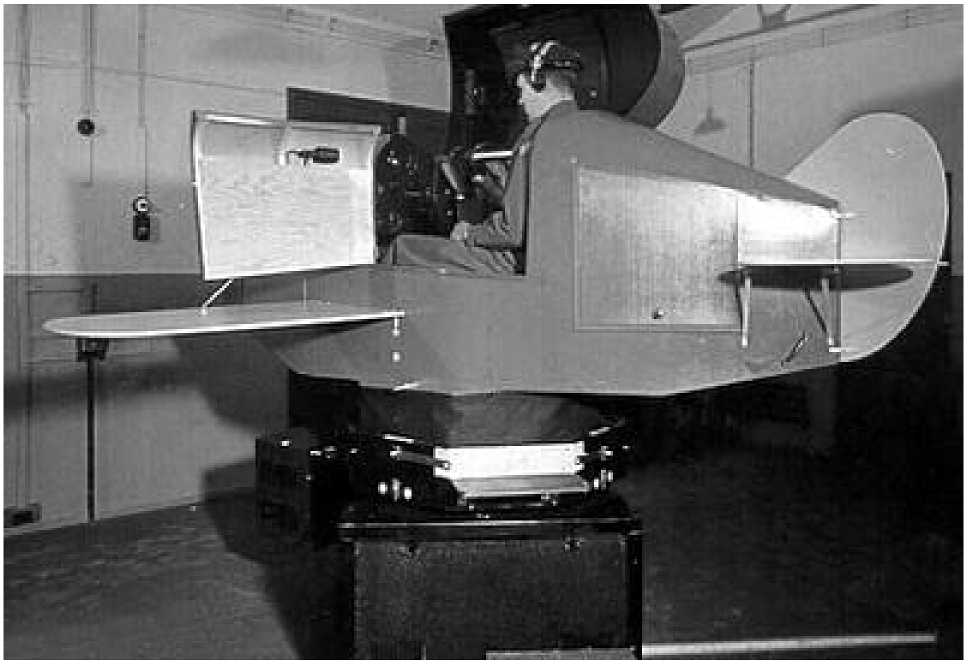
Full-flight simulator development

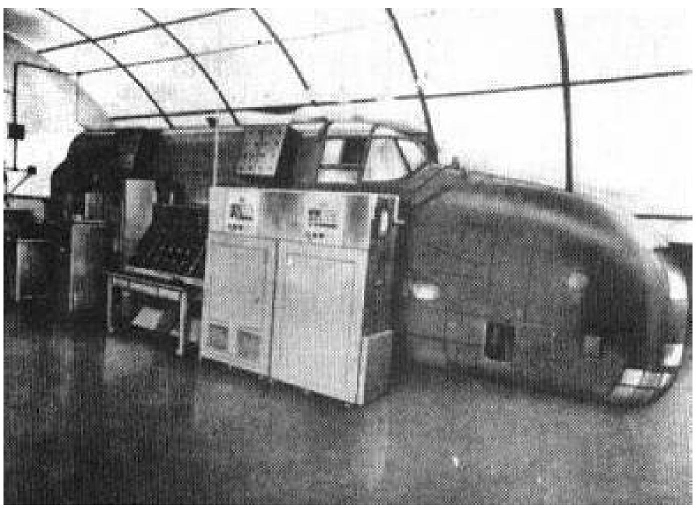
In 1928, Edwin C. Link left his father's organ building business to begin work on a "pilot trainer." He envisioned a device that would allow pilots to take their preliminary flight instruction while remaining safely on the ground. With his background in organ building, he utilized air pump valves and bellows to make his trainer move in response to its controls. Introduced in 1934, it was later used for instrument flight training for virtually all North American pilots during World War II and was still in widespread use in the mid 60s. With a rudimentary motion system and no visuals, it



Early flight simulator circa 1910.



Link flight trainer.



Silloth trainer, 1945.

certainly had no pretensions to replicate any known aircraft; its sole purpose was to allow the pilot to learn to fly, and then practice, instrument procedures.

In the early 1950s, with the advent of more complicated aircraft, the actual cockpit itself was used as a simulator. Taken from the production line and placed in the training center, it was clearly an accurate representation of the cockpit. The aerodynamic model was rudimentary, driving little more than the flight instruments in response to flight control inputs, and there was no motion or visual system; however, it provided valuable training and laid the foundations for further simulator developments. At this stage, the training conducted in the simulator also expanded to include normal and emergency procedures.

Motion system

In an attempt to increase the realism of simulator training, motion was introduced. There has subsequently been a great deal of debate within the flight simulator industry on the need for motion, and many accident investigations have utilized engineering simulators that invariably have no motion systems.

Is motion necessary in either case? To attempt to answer this question, the RAND Corporation conducted a study in 1986 that evaluated U.S. pilots flying the C17 flight simulator and showed that their performance was greatly enhanced through the use of a motion system. This should not be surprising; in the real world, acceleration precedes displacement and, since our motion sensors detect acceleration very quickly, cues of motion precede visual displacement.

Research has indicated that the brain senses acceleration first (sec/100) whereas visual displacement cues follow (sec/10). When flying an aircraft, the pilot has three main input sources of information

- The eyes, which provide his main input. The information from the instruments tells him his attitude, position in a space, and, to a lesser extent, the rate of change of these variables.
- The limbs, which tell him the position of the aircraft controls together with the force that he is exerting on them.
- The vestibular system, which tells him when he is subjected to acceleration and, importantly, also stabilizes his eyes.

Let us now consider the pilot in a flight simulator equipped with a good quality, low-latency motion platform and consider a sudden disturbance in flight. The pilot's vestibular system immediately alerts him to the disturbance, because it responds rapidly to the acceleration cues; and although this information may not tell him the exact nature of the disturbance, he is warned to monitor the instruments to detect a change.

Since the instruments generally indicate the attitude or position of the simulator, the second integral of acceleration, there will be a delay following the acceleration before the instruments show the result of the disturbance. However, the pilot will now be primed to notice this change in indication as soon as it is discernible and can apply an immediate correction by means of the aircraft controls. This brings another feedback loop into operation that tells the pilot how much he has moved the controls together with the force resisting the movement. The acceleration generated by these controls is again sensed by the pilot's vestibular system, and he is aware that the correction is taking effect even though the instruments may still be indicating the results from the initial disturbance.

The pilot is thus able to predict what is going to happen to the simulator by means of these feedback loops and thereby utilize identical strategies to those used in the aircraft. It should, therefore, be clear that any meaningful assessment of pilot behavior in an investigation should *only* be conducted on a simulator with a high-fidelity motion system.

The civil regulations have recognized the importance of motion, and only a device with a motion platform is called a full-flight simulator. Current regulations require a maximum time of 150 milliseconds from the initial input to the last effect (normally visual), but this maximum time may well be reduced in the future to reflect the increasing capability of motion systems.

Modern motion platforms are usually driven by six hydraulic actuators; by sending appropriate commands to all six actuators simultaneously, motion in any of the aircraft's six degrees of freedom can be obtained. But even the best motion systems have their limitations. This is not surprising when we consider that we are asking these six actuators, each about 5 feet in length, to provide all of the typical motion and vibrations cues experienced throughout the flight envelope of the aircraft, but while remaining firmly anchored to the ground.

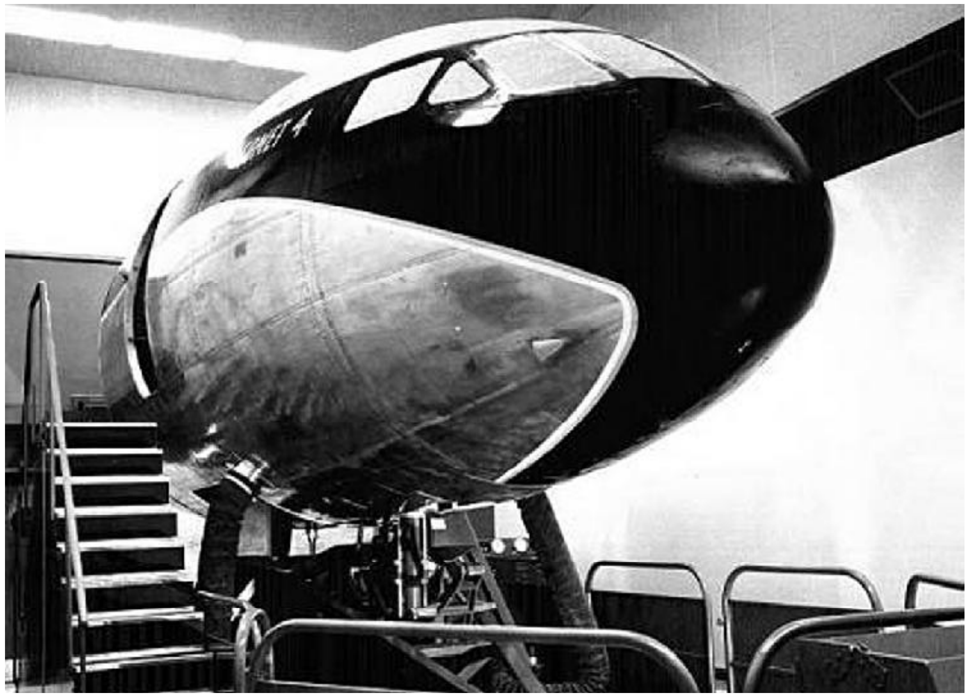
It has not been possible, so far, to generate prolonged "g" and thus prolonged feedback cues to crews; this means, for instance, that during a tightening turn onto a final approach there will be no increase in stick force, an important cue to the pilot. Some simulators have attempted to introduce this cue but with varying degrees of success. Rejected takeoffs are an obvious area where there is simply not enough motion available to generate the correct cues.

However, perhaps one of the most significant problems is that motion is not an exact science and is still correctly regarded as a "black art." There are always compromises to be made. One operator may decide that he requires a strong motion cue to simulate heavy braking and is prepared to accept the subsequent false cue provided by the high level of washout; another operator may prefer weaker motion cues but with no false cues. The only way to prevent any false cues from being generated is to tune the system down until you cannot really feel anything. In addition, special effects are often exaggerated in order to conceal the lack of motion. How is the accident investigator to make sense of this?

Visual system

The next step toward increased realism was to incorporate a visual system. Early systems used a model board, but computer-generated displays soon became available. Initially these were only capable of providing night/dusk scenes through a monitor display system with a limited field of view. Modern systems provide night/dusk/daylight scenes with realistic weather simulations and a horizontal field of view of 240° and 60° in the vertical. Of all the elements that comprise the modern flight simulator, perhaps the most immediately impressive is the visual system. With the increased capability and availability of satellite imaging, together with the dramatic increase in economically priced computing power, the visual image is seductively authentic.

Earlier visual scenes had a somewhat sterile appearance. Thus an airport would consist of a runway, with its attendant lighting, surrounded by grass and some stereotypical buildings. With little "depth" in the scene and little to no textural feedback, there were poor visual cues for the pilot during precise events such as the landing flare. Modern visual systems incorporate high levels of detail in areas such as the airport, but the dilemma facing the visual modeler is that the volume of data representing this scene is almost infinite, yet the image generator will only accept a finite number of polygons (shapes) and textures. Texture is used like digital wallpaper and brings a lifelike quality to otherwise sterile scenes without increasing the polygon count. It is typically used on flat surfaces such as grass, buildings, etc., but is also the technique used to display airport signs, people, and vehicles.



Comet IV flight simulator with pitch motion system, 1958.

Importantly, texture is also used on runway surfaces, and, while it may appear to be realistic from a distance, the texture surface produces an indefinite landing surface with little detail apparent during the final 30 feet prior to touchdown. Once again the pilot is deprived of realistic visual cues during the landing.

There are other facets of current visual systems that do not assist the pilot during the flare maneuver, such as restricted peripheral field of view on the older simulators, the importance of which, I suspect, is not really understood. Exactly what sensory inputs does the pilot process during the landing flare, and what are their relative importance? Until we honestly understand this process, the simulator manufacturer does not know, with certainty, what he should provide in the simulation and the accident investigator is groping in the dark.

One of the practical problems associated with the visual database is keeping pace with the real world. For example, I recently conducted training in all-weather operations in a modern flight simulator. The airfield in use was Manchester, U.K., which has had a second runway for 4 years, but this was still missing from our simulator visual database. It was decided that this did not affect the training needs, but would this be satisfactory in an accident investigation where the rapid assessment of the visual scene is an important element of the pilot's decision-making process and thus workload?

Conclusions

Having considered the development of the flight simulator, it would be expected that modern examples would be able to replicate accurately the spatial layout of the cockpit. However, it may be pertinent to note that the cockpit is only simulated back to a defined line, usually around the back of the pilot's seat; the locked cockpit door, with its attendant distractions, is not simulated. It would also be expected that the cockpit controls, together with their force feedback, accurately represented those in the aircraft, as did all displays. However, both the motion and the visual systems have their limitations.

Most crucially, the weakest area for these important subsystems is that of integration, both with each other and the simulator as a whole. Any failure in integration will affect the performance of the pilot, albeit at a subconscious level. However, if an understanding of pilot behavior is part of your quest, and it is difficult to accept that the investigator would not be seeking answers here, then you will have to be sure that all of the variables have been taken into account.

The regulatory framework

Flight simulators are used as a means to acquire, maintain, and assess flightcrew proficiency, and those simulators operating within the civil sphere are designed to meet international regulatory requirements. The current definitive standard is a Level D simulator that allows for zero-flight-time training. The basic premise for the qualification of a full-flight simulator was, and still is, that since the training and testing of the aircrew would normally be conducted in a real aircraft, any alternative to this must possess exactly the same characteristics and level of realism as the aircraft. Thus, once the regulators have evaluated the simulator to prove that it adequately represents the aircraft, they will grant a ***Qualification***, which implies a certain level of realism in comparison to the aircraft. Other factors are then involved in deciding the training tasks that may be carried out in the simulator, a process that is known as ***Approval***.

The simulator is constructed using "design data," which originate from the aircraft manufacturer, supplemented by data from the vendors of any equipment fitted to that aircraft that can affect the realism of the simulation, e.g., engines, autopilot, flight management systems, etc. The simulator performance is then compared against the "check-out data." The data should have been collected from inflight recordings on a particular aircraft of the type being simulated. Once the simulator demonstrates that it matches the check-out data, and when other objective and subjective tests have been completed, it receives its qualification.

Malfunctions

Most malfunctions on modern aircraft types are part of, or supported by, the data pack and reflect correctly the procedures in the aircraft operating manual. Modeling component failures in these types invariably provides a correct simulation for the subsequent effects. The more reputable aircraft manufacturers now also provide simulation models that can be incorporated directly.

Other malfunctions are the result of discussions between the simulator manufacturer and the operator who agree between them the cause and effect. But during the acceptance phase, it is common for the operator's pilots, who are often senior training captains, to insist upon altering elements of the malfunction. One example that is repeatedly seen relates to engine failures after takeoff. Since this is one of the mandatory elements of training required during the pilot's routine simulator checks, it is quite understandable that the acceptance pilots should wish to ensure its fidelity, and they will often demand more or less roll or yaw accompanied by higher or lower rates of motion. When I asked one senior training captain what he was using as his comparison, he explained that he had suffered just such a failure in a Boeing 737-200, but he was accepting a Boeing 777! It is also common for acceptance pilots to base such judgments on the performance of other simulators that they have flown.

Engine failures in the simulator generally have muted responses in both motion and sound, but when reading reports of pilots suffering engine failures or surges in aircraft, they will often use phrases such as "It was like hitting a brick wall."

However, as long as the acceptance pilot does not deviate too far from the baseline malfunction, whatever that is, who is to say that he is wrong? The simulator will be approved for training, but is the engine failure that is modeled in the simulator the same as that which you are investigating? Engine failures in the simulator generally have muted responses in both motion and sound, but when reading reports of pilots suffering engine failures or surges in aircraft, they will often use phrases such as "It was like hitting a brick wall."

Two issues fall from this. Firstly, if the pilot has been trained in a simulator that provides a different response to the aircraft during an engine failure, or any other malfunction, then has he been taught inappropriate behavior? If so, and he then makes a mistake in his initial reaction to the failure, is it pilot error or a systemic error?

Secondly, during the subsequent investigation, how does the investigator evaluate what cues the pilot used to identify the failure? I have suffered one engine failure and two engine surges in my career, and in all instances it was a combination of the sound and motion cues that warned me of the malfunction. We have not even discussed the importance of sound to the pilot—for both normal and non-normal operations. It should be easy to obtain during routine operations even if we cannot capture the sound of an engine surge. But was that recording of normal operations completed with the flightdeck door open? If that is the case, the background sounds of air conditioning and engines are unrepresentative, as is the sound associated with the engine failure, or do we just pretend that sound is not important?

We have already accepted that modern flight simulators accurately represent the spatial orientation of the cockpit, but what happens with "combo" simulators, i.e., those that represent more than one aircraft type?

For instances, there are many simulators that represent both the Boeing 757 and the 767, and pilots will often have a rating that covers both types. However, to reduce costs and to ensure that the "down time" between simulator slots is kept to a minimum it is accepted practice that much of the overhead panel and control stand is left in place for both aircraft types, even though some of the controls are different. For example, on these aircraft types, the hydraulic control panel, stabilizer trim indicator, and stabilizer trim cut out switches are different, as are others systems to a lesser degree. Where is the fidelity here, and how can the accident investigator make valid judgments, unless he has carefully considered the consequences? Similar problems may also occur with the Airbus A330 and A340.

Within the simulator industry, it has long been recognized that extraneous activity that can affect a pilot's workload is often not incorporated into the flight simulator. In an attempt to more accurately reflect the distractions encountered when flying into a busy airport, modern flight simulators now have the capability to introduce extraneous air traffic transmissions, and the more capable visual systems have much more traffic around, both on the ground and in the air.

But there are other facets of simulation that more immediately affect the pilot. For example, ADF needles in simulators are invariably deadbeat whereas this is rarely seen in an airplane, and it has a real impact on the mental workload. Smoke, together with the need to fly with oxygen masks donned, creates a very difficult cockpit environment, and although smoke has been available on simulators for many years it is not frequently used. In the U.K., for example, it is a requirement to inform the local fire brigade because prior to the use of smoke the fire alarms have to be disabled—otherwise the alarms will operate and may also initiate the sprinkler system!

Modeling and its limitations

What is involved in the process of simulation? Simulations are essentially dynamic processes that attempt to represent the behavior of some aspect of the real world. Flight simulation sets out to represent the behavior of a specific aircraft. However, in the flight simulator, apart from the physical representation of the cockpit interior, the aircraft simply does not exist. It is represented by a series of interrelated mathematical models that attempt to mimic the handling characteristics of the aircraft and its various systems. Moreover, the ground and the air environments in which it appears to perform are also only mathematical models. Thus the basis of the simulation is a family of models responding to each other in such a manner that their outputs, if channeled through a suitable device (the simulator), will give those in the cockpit the impression of being in control of an aircraft operating in the real world.

Therefore, most modeling in the simulator, and particularly aerodynamic modeling, can only provide an estimate. Once you move from the data point, there is no longer any defined precision. It is accepted practice to interpolate between data points within the cleared flight envelope since this will probably not lead to erroneous responses; however, how should the modeling be extrapolated outside of this flight envelope? This does become important when considering, for example, the use of flight simulators in upset recovery programs with their attendant excursions in both pitch and sideslip. Thus, while the collection of models may give the illusion of an aircraft in flight, they do not constitute an aircraft, even when flown aircraft data are used for the design and validation of the simulation. This produces limitations for the accident investigation that must be recognized.

MD-11 flight simulator.

The models on which a simulation is based are unlikely to fully represent the real world because of their range, complexity, and variability. For instance, flutter is not modeled in any flight simulator that I am aware of. Moreover, some elements may be absent because of a lack of understanding of their influence or even of their existence. Even when the models are fully understood, the designer of the simulation is often forced to simplify the representation of the real world in order to produce useable models.

In addition, the operator or the manufacturer of the simulator may also restrict the level of detail contained in the simulation models. Knowing that modeling is an expensive process, neither will want to include more complexity than is thought necessary to achieve the training objectives. This clearly has ramifications for the accident investigation where there are differences between the questions to be answered during the investigation and the training needs for which the simulator was designed.

Furthermore, the fidelity of the flight simulator is based upon the quality of the data package, and while many of these are excellent, some are not very good. In addition, the individual aircraft systems are developed separately from within this package; and if they do not integrate seamlessly, then the overall fidelity of the simulator will suffer. Moreover, system engineers, while excellent software engineers and very knowledgeable, may have had little or no experience in actually operating an operational system, e.g., an aircraft braking system.

Implementing the model

The full-flight simulator is a ground-based training aid, and despite the use of advanced computational techniques, sophisticated visual systems, and cockpit motion systems employing acceleration-onset cueing, it will have physical limitations to the extent to which it can represent the aircraft. It is important to remember that the simulator is successful because it does not conform to behaving like an aircraft: The aircraft cannot freeze its position in space, translate from one position to another in any direction, land without taking off, repeat a maneuver precisely, or operate safely outside of its normal performance envelope.

In commercial aviation, the aircraft that the simulator is attempting to represent is rarely stable, as various fleet modifications are introduced. Sometimes these arise across the whole fleet, and on others the variation may exist only on recently introduced versions of the aircraft. In an ideal world these changes would be immediately reflected in the simulator; but if the simulator does not retain an absolute resemblance to the aircraft, how valid are any of the conclusions made by the accident investigator? Some persons may argue that absolute compatibility with the aircraft is unnecessary if it only involves the positioning or standard of an avionics unit, e.g., the TCAS display or a radio control box. But how then can one accurately assess the pilot's workload and the effect this may have had on his performance? This problem has increased in recent years because of the number of different variants of a particular aircraft being offered by the aircraft manufacturer and has been compounded by the emergence of flight training centers that cater to a number of different customers with dissimilar aircraft.

For example, each different engine fit results not only in different performance characteristics but also potential aerodynamic variables due to the engine cowling/pod design. Additionally, modern "fly-by-wire" aircraft employ sophisticated avionic units in their control systems. These units are populated with both "firmware" and "software" that can be and frequently are modified, both during aircraft development and while in service. To ensure that the concept of the use of flown data for simulator validation remains inviolate would require that the aircraft manufacturer retains an instrumented test aircraft, in each configuration, available at all times. This would clearly be financially unacceptable.

Therefore, the aircraft and simulator manufacturers have proposed that, so long as one set of original data is based upon aircraft tests, it is possible to substitute alternative data for the variant models. The most commonly accepted substitute is the use of engineering simulator data. The problem is that these same regulatory bodies that are supposed to approve the use of the substituted data are often not staffed with personnel capable of monitoring the validity of this computer-generated data.

But even more fundamental problems can occur during the lifetime of an aircraft. For example, the Jetstream 31 aircraft was originally designed with and entered service with a four-bladed propeller driven by a 900 shp Garret engine, and the associated simulators used the appropriate data for both qualification and approval. However, the same aircraft finished its life with an engine producing 1,020 shp, but this has not been incorporated into the simulator. Any investigation into an accident involving engine malfunctions or any handling qualities assessment would clearly be affected by this change.

They are also excellent for evaluating the time frames at which events occur; at least we can then begin to appreciate the problems facing the pilot. However, weaknesses exist relating to both the motion and visual cues, and particularly their integration.

Summary

Flight simulation has become an indispensable tool for training within aviation and has established a reputation for high levels of fidelity. Flight simulation has also proven itself to be an invaluable tool for the accident investigator, but the seductive level of "fidelity" might lead the unwary investigator to draw invalid conclusions. In order to reduce the possibility of this occurring, the investigator needs to follow a simple plan.

Consider carefully what is required from the simulator assessment. Flight simulators are good if you need to understand the sequence of a systems malfunction, or the manner and rate at which information is provided to the pilot, although this may not be true of an older flight simulator. They are also excellent for evaluating the time frames at which events occur; at least we can then begin to appreciate the problems facing the pilot. However, weaknesses exist relating to both the motion and visual cues, and particularly their integration. The detailed modeling on which a simulation is based may also be imperfect, and it would be wise to develop a clear understanding of the precise nature of the physical differences between the particular aircraft and the chosen simulator. Any excursion from the cleared flight envelope should be considered a "best guess," because that is all that it is, and be very careful with any workload assessment.

Having considered what is required, it is then necessary to discuss the detail of the assessment with both the simulator manufacturer and the aircraft operator. The manufacturer will understand the simulation issues and, when prompted with the correct questions, will be able to explain their limitations. The operator will be able to explain the standard operating procedures and how their training is conducted. For example, how were their pilots taught that a certain system worked? How does this correlate to the simulation of that system? How were their pilots taught to respond to a particular malfunction? With answers to these questions, it is probable that valid conclusions can be drawn from the simulator assessment and the best use will have been made of this unique investigative tool. ◆

What Limited Data Sets Can Reveal

Computer animation of limited data sets can provide valuable information that is not readily apparent from a data listing.

By Neil Campbell (MO3806), Australian Transport Safety Bureau

(This article was adapted, with permission, from the author's presentation entitled Flight Data Analysis Using Limited Data Sets *presented at the ISASI 2004 seminar held in Australia's Gold Coast region Aug. 30 to Sept. 2, 2004. The full presentation is on the ISASI website at www.isasi.org.—Editor)*

The use of computer graphics to animate flight data recorder (FDR) or quick access recorder (QAR) information is well-known. It is a valuable investigation tool as well as a powerful medium to provide communication and education. With newer aircraft, the FDR or QAR will record a comprehensive range of parameters that accurately define its performance and operation.

However, with general aviation aircraft, most helicopters, or older-generation air-transport aircraft, there may be no FDR and only a limited number of parameters will be recorded by other systems. At the Australian Transport Safety Bureau (ATSB), animations have been produced using limited data sets, including:

- radar data.
- global positioning system (GPS) data.
- electronic control unit data (e.g., engine data).
- basic FDR parameters.

In this article we present the case study from a Bell 407 helicopter accident. Two sources of recorded data were available for this investigation: ground-based radar data and onboard electronic control unit (ECU) data

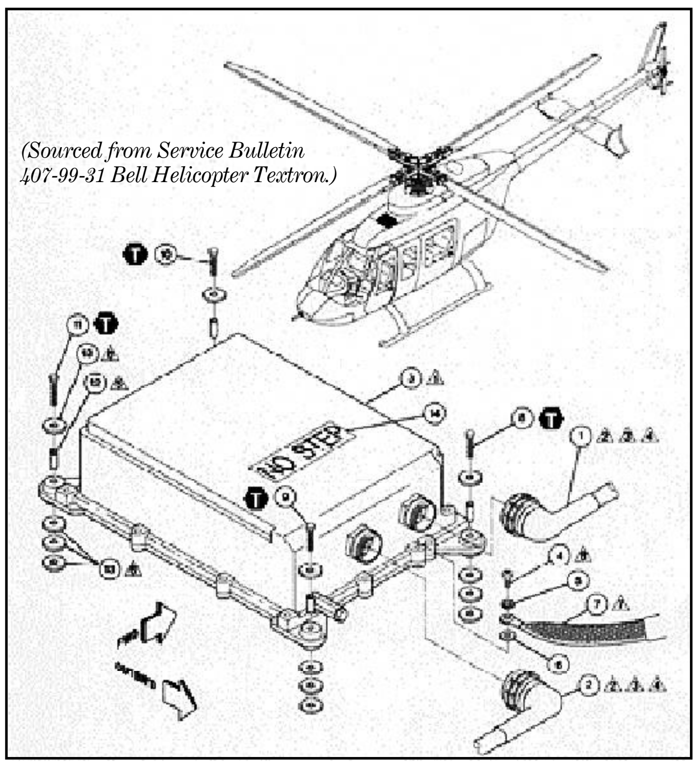
Radar data

Primary radar returns are produced by radar transmissions that are passively reflected from an aircraft and received by the radar antenna. The received signal is relatively weak and provides only position information. Primary radars, which are only located near capital city airports, have a nominal range of 50 nm.

Secondary radar returns are dependent on a transponder in the aircraft to reply to an interrogation from the ground. The aircraft transmits an encoded pulse train containing the secondary surveillance radar (SSR) code and other data. Pressure altitude may be encoded with these pulses. As the aircraft transponder directly transmits a reply, the signal received by the antenna is relatively strong. Consequently, an aircraft that has its transponder operating can be more easily and reliably detected by radar. Civilian secondary surveillance radars are located along the east coast of Australia to meet the operational requirement of radar coverage from 200 nm north of Cairns to 200 nm west of Adelaide. Coverage within a 200 nm radius of Perth is also required.

A transponder-equipped aircraft is not always detected by secondary radar. This could be due to one of the following reasons:

- aircraft is outside of the range of the radar,
- transponder is not switched on,
- transponder is unserviceable,
- loss of aircraft power to the transponder,
- terrain shielding, and



(Sourced from Service Bulletin 407-99-31 Bell Helicopter Textron.)

Figure 1

***Neil Campbell** graduated in 1983 with a bachelor of engineering degree (electronics) from the University of Western Australia. In 1986, he joined the Bureau of Air Safety Investigation as a flight recorder specialist. During 1998, he was a member of the ICAO Flight Recorder Panel, which developed changes to ICAO Annex 6. In February 2000, he joined the Corporate Safety Department of Cathay Pacific Airways Limited in Hong Kong. During 2001 and 2002, he held the position of manager of air safety. In December 2003, he rejoined the Australian Transport Safety Bureau as a senior transport safety investigator.*

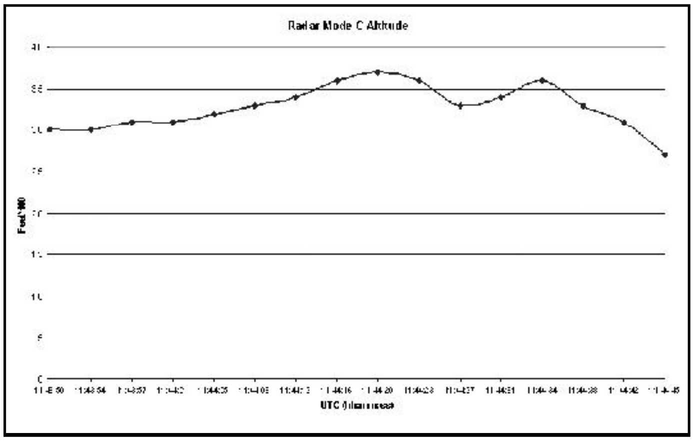


Figure 2

• aircraft transponder aerial is shielded from the radar due to aircraft maneuvering.

The radar rotates at 16.2 RPM giving a scan rate of 3.7 seconds. The accuracy of the radar position data is proportional to the range of the aircraft from the radar site. Typical accuracies for a monopulse SSR are range accuracy: ± 0.05 nm RMS and azimuth accuracy: ± 0.05° RMS. The overall accuracy can be affected by terrain or meteorological conditions. The Mode C pressure altitude data accuracy is determined by the aircraft's encoding altimeter accuracy plus the transponder quantization of 100 feet. An encoding altimeter can suffer from lag when experiencing high vertical speed changes.

ECU data

The Bell 407 was fitted with a Rolls-Royce 250-C47B turbine engine. The ECU is a component of the engine full authority digital electronic control (FADEC) system. The ECU was located forward of the main rotor transmission (refer to Figure 1).

The ECU has a non-volatile memory (NVM) that can store engine and other parameters. When it detects an exceedance, it functions as an incident recorder and is designed to store 60 seconds of data commencing 12 seconds prior to the start of the exceedance.

Parameters

The following parameters were recorded:

Mnemonic:	Name:	Units:
Timestamp	Cumulative Engine Run-time	hhh:mm:ss.sss
Nr	Rotor Speed	%
Ng (N_1)	Gas Generator Speed	%
Np (N_2)	Power Turbine Speed	%
MGT	Measured Gas Temperature	°F
Q	Torque	%
Wf	Fuel Flow	pph
NDOT	Rate of change of Ng	%Ng/sec
P1	Ambient Pressure	psi
Mode	Engine Control Mode (Automatic/Manual)	1=Auto
CP	Collective Pitch	%
PLA	Power Lever Angle	Degrees
T1	Compressor Inlet Temperature	°F

Each parameter was sampled 22 times covering a period of 25.2 seconds.

Sampling rate—Each parameter was sampled every 1.2 seconds. When an exceedance occurred, an additional sample of each parameter was recorded.

Timing overlap—Radar data are time stamped with UTC that is synchronized with UTC obtained from GPS. ECU data are time stamped with elapsed time relative to the initiating exceedance. As these two time sources were not synchronized, it was necessary to determine by other means whether an overlap of the two data sets had occurred.

The following observations were made from the radar data:

- The final radar return was recorded at 1144:45 UTC at an altitude of 2,700 feet (Mode C).
- The latitude and longitude of the final radar return were located very near the crash site (within 0.1 nm).
- The final series of returns indicated that a substantial vertical speed had developed.
- The initial loss of returns was probably due to terrain shielding.
- The helicopter subsequently did not climb high enough for radar returns to again be received.

The following observations were made from the ECU data:

- The recording of ECU data ceased when impact occurred.
- The ECU stored data from the last 25 seconds of flight.
- Data latency was small as the engine data recorded by the ECU were directly available and not transmitted by other systems.

Considering the above observations, it was considered highly likely that the radar data and ECU data did overlap in time and that the maneuver leading to the development of the substantial vertical speed, initially captured by radar, was the same maneuver subsequently captured by the ECU.

Pressure altitude was the only common parameter, and it was used to try and correlate in time the two data streams.

Radar Mode C pressure altitude—Pressure altitude referenced to 1013.2 hPa was recorded with a resolution of 100 feet. The source of the pressure altitude was an altitude encoder in the helicopter. A static source provided static pressure to the encoder. Mode C pressure altitude is monitored by ATC, and in comparison to the altitude derived from the ECU it was considered to be accurate but limited by resolution. (Refer to Figure 2.)

As the reported QNH was 1014 hPa, approximately 30 feet needed to be added to the recorded Mode C values to give pressure altitude referenced to QNH.

ECU ambient pressure—The ECU recorded ambient pressure that was used for fuel scheduling purposes. It was sourced from an open port on the ECU itself. The port was not connected to a static pressure line. Given its location, it was susceptible to pressure fluctuations due to airflow from the main rotor.

Ambient pressure is an accurate indicator of pressure altitude

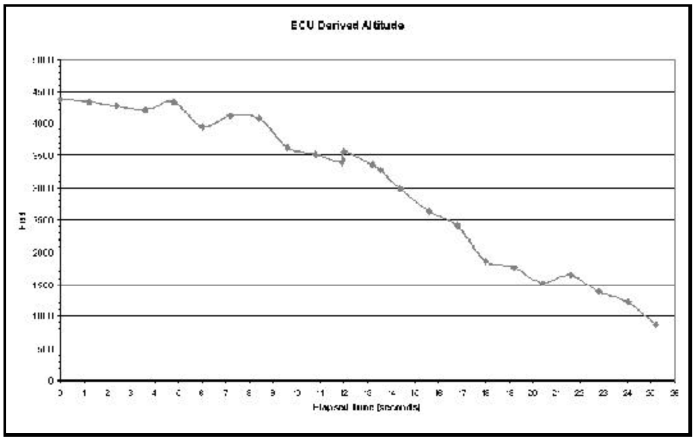


Figure 3

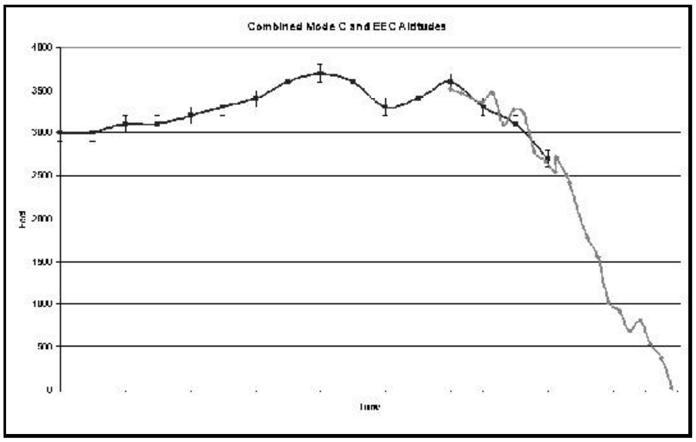


Figure 4

as long as certain assumptions are met. One assumption is that an accurate source of static pressure is available, and, if so, standard conversions can be used to convert pressure to altitude. This assumption was not satisfied for the ambient pressure data recorded by the ECU, and corrections needed to be applied to convert it to pressure altitude. (Refer to Figure 3.)

ECU Pressure altitude offset—The highest Mode C pressure altitude recorded was 3,700 feet, and the highest pressure altitude obtained from the ECU was 4,370 feet. This indicated that the ECU was over-reading by at least 670 feet.

The final pressure altitude obtained from the ECU was 870 feet. Given the small data latency expected for the ECU, this value was the approximate sea-level value allowing for the sampling interval of 1.2 seconds.

Timing correlation—Overlaying the Mode C and ECU pressure altitude traces showed that a good match was obtained when the ECU altitude was offset by -850 feet and the end of the Mode C trace was overlapped by the start of the ECU trace. The duration of the overlap was approximately 11 seconds. The tolerance of the duration of the overlap is considered to be ± 2 seconds. (Refer to Figure 4.)

Animation of the ECU data—While computer animation is recognized as being a very useful means of assimilating large quantities of information, it is also very useful when analyzing limited data sets such as the ECU parameters.

The ECU data were imported by the ATSB's Hewlett Packard C3000 computer for presentation using RAPS version 5.0 software.

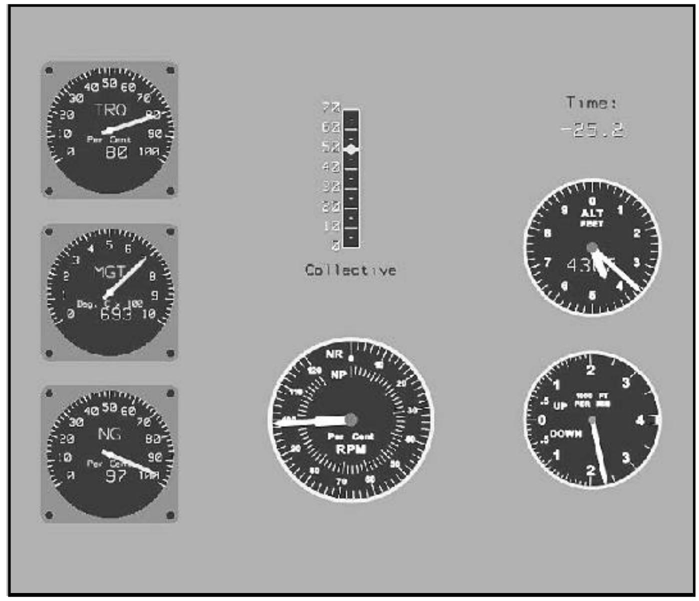


Figure 5

A simulated instrument panel was developed to display key parameters in real time. (Refer to Figure 5.)

While the ECU sampling interval was 1.2 seconds, the frame rate of the animation was much higher, e.g., 100 frames/sec. Intermediate values were linearly interpolated.

Torque instrument—The pointer and digital display were directly driven by the ECU torque data.

MGT instrument—After the values in degrees Fahrenheit were converted to degrees Celsius, the pointer and digital display were directly driven by the ECU MGT data.

Ng instrument—The pointer and digital display were directly driven by the Ng data.

Collective display—The pointer and digital display were directly driven by the collective data. Rolls-Royce advised that maximum collective corresponded to a recorded value of approximately 60%.

Nr/Np % RPM instrument—The pointer and digital display were directly driven by the Nr/Np data.

Time—A time counter in seconds with the zero datum at the end of the ECU recording, i.e., at the time of impact with the water. A value of –25.2 corresponds to the start of the ECU data.

Altimeter—The ECU ambient pressure data (psi) were converted to pressure altitude. The pressure altitude was smoothed and used to drive the display.

Vertical speed indicator—Derived from the rate of change of pressure altitude.

The animation was very useful in showing the correlation between parameters, e.g., the relationship between Nr/Ng due to governing. These relationships are not always evident from a data listing. It also put the data into time perspective.

Non-FDR data are becoming increasingly available from accidents involving general aviation aircraft and smaller helicopters. While these aircraft do not require an FDR, they are often fitted with avionics that can store data.

Analysis of this data can be very useful to an investigation. Computer animation of these limited data sets can provide valuable information that is not readily apparent from a data listing.

Data obtained from sources other than the FDR may be inaccurate and uncalibrated and require careful analysis. ◆

Lederer 2005 Nomination Deadline May 30

The ISASI Awards Committee is seeking nominations for the 2005 Jerome F. Lederer Award. For consideration this year, nominations must be received by May 30.The purpose of the Jerome F. Lederer Award is to recognize outstanding contributions to technical excellence in accident investigation. The Award is presented each year during the annual seminar to a recipient who is recognized for positive advancements in the art and science of air safety investigation.

The nomination process permits any member of ISASI to submit a nomination.

The nominee may be an individual, a group of individuals, or an organization. The nominee is not required to be an ISASI member.

The nomination may be for a single event, a series of events, or a lifetime of achievement.

The ISASI Awards Committee considers such traits as duration and persistence, standing among peers, manner and techniques of operating, and, of course, achievements.

Once nominated, a nominee is considered for the next 3 years and then dropped. After an intervening year, the candidate may be nominated for another 3-year period.

The nomination letter for the Lederer Award should be limited to a single page.

This Award is one of the most significant honors an accident investigator can receive; therefore, considerable care is given in determining the recipient. ISASI members should thoughtfully review their association with professional investigators, and submit a nomination when they identify someone who has been outstanding in increasing the technical quality of accident investigation.

Nominations should be mailed, or e-mailed, to the ISASI office or directly to the Awards Committee chairman, Gale Braden, 2413 Brixton Road, Edmond, OK 73034 USA, e-mail address geb@ilinkusa.net. ◆

Correction

In the "G'day ISASI" article published in the last issue, we failed to recognize Andrew Warland-Browne, Michael Nendick, Réal Lavasseur, and Dr. Steve Bell for their involvement in presenting the Communicating and Educating tutorial. Further, the handout paper quoted in the article was titled "Training, Education, and Promotion of Safety: What Are They and How Do We Do It." It was written by Dr. Bell.—*Editor*

Canadian Society Elects Executive

The 2005 elections for the Executive for the Canadian Society of Air Safety Investigators is now complete. Three nominations were received, one for president and two for vice-president. Elaine Parker, the incumbent vice-president, chose to accept the position of secretary-treasurer in order to complete the slate of three officers for the Canadian Society. As a result, the CSASI Executive for the next 2 years will be as follows: Barbara Dunn, president; Barry Wisznioski, vice-president; and Elaine Parker, secretary-treasurer.

At the most recent ISASI Council meeting, Dunn reported that the Canadian Society membership exceeded 100 members and that the Society was in sound financial condition. ◆

ATS Working Group Reports Progress

The ATS Working Group continues to progress with cooperative projects related to the investigation of ATS safety occurrences.

The Group has six projects in the works at this time relating to issues including the provision by ATC of IFR terrain clearance to runway safety initiatives. An international flavor is delivered by the diversity of member contributions. A revised Terms of Reference for the ATS Working Group has been provided to ISASI President, Frank Del Gandio, for consideration.

The Group has been most deeply moved by the tragic events generated by the Asian tsunami. It is willing to consider any request for technical support that may assist fellow ISASI members to rebuild their aviation and safety infrastructures.

MOVING?

Please Let Us Know

Member Number__________________

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

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Address ________________________

City ___________________________

State/Prov. ______________________

Zip ____________________________

Country ________________________

New Address*

Name __________________________

Address ________________________

City ___________________________

State/Prov. ______________________

Zip ____________________________

Country ________________________

E-mail _________________________

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

Should any ISASI member wish to comment, contribute, or actively support the ATS Working Group agenda, they are encouraged to contact Chairman John Guselli at jguselli@bigpond.net.au or Secretary Bert Ruitenberg at b_ruitenberg@compuserve.com at any time for further information. ◆

ISASI Reachout Sets Early 2005 Plans

"The ISASI Reachout program continues to attract attention around the world and the expanded program has resulted in new invitations for workshops," said Jim Stewart, program chairman. The next workshops are scheduled for Taipei, Taiwan, and Seoul, Korea, in May of this year.

A 2-day safety management systems workshop will be hosted by Eva Airlines in Taipei on May 10 and 11. From Taipei, the instructing staff will travel to Seoul to conduct their first 5-day safety management system workshop from May 16-20 to be hosted by the ICAO COSCAP-NA program and the Korean CAA (CASA). An accident investigation course to be presented in Seoul is also in the planning stages for 2006.

The ISASI Reachout program has trained more than 1,000 aviation specialists worldwide and has received extremely positive feedback from participants and hosts alike. The program has reached all levels of aviation in many countries and has served as a catalyst for the introduction of improved accident investigation and safety management to government and corporate organizations.

During meetings at ISASI 2004 in the Gold Coast, Australia, corporate members of ISASI requested that we increase information on ISASI Reachout. Stewart said, "The committee will be developing a newsletter on Reachout activities for the information of corporate members. On behalf of ISASI, I wish to thank the many corporations that have contributed to the success of the Reachout program." ◆

Buck Welch Assumes GA Working Group Chair

William B. (Buck) Welch, Ed.D., (MO3092) long-term ISASI member and senior accident investigator accepted President Frank Del Gandio's appointment as chairman of the newly instituted General Aviation Working Group.

The new initiative was first raised by members. "I received feedback from some of our members in the general aviation sector who saw value in establishing representation specific to general aviation within ISASI, to address more specifically the issues that affect that sector's role in accident prevention and its investigation," noted President Del Gandio in presenting the issue to the governing Council. The Council determined that support for such a group was feasible, and approved its creation with an aim toward an increase in membership of investigators trained in the specialties of general aviation investigation.

Dr. Welch has recently returned to the aircraft accident investigation industry as section supervisor of Cessna Aircraft Company's Product Safety Group. He spent the last 2 years as a Textron Six Sigma Black Belt leading process improvement teams for the Cessna Aircraft Company. Prior to being nominated for the Textron Six Sigma program, Dr. Welch spent 14 years as a senior aircraft accident investigator. He investigated Cessna accidents worldwide and assisted the National Transportation Safety Board, Federal Aviation Administration, and local officials as a technical representative during the on-site investigations. He also assisted in aircraft accidents involving foreign countries, through the guidelines set forth by the International Civil Aviation Organization. Over the 14 years, he has participated in more than 250 field investigations. He also holds an adjunct instructor's position at Oklahoma State University and has instructed its aircraft accident investigation course to graduate and undergraduate students since fall 2002. ◆

IN MEMORIUM

Nicholas R.J. Gwyn (MO3668)
Ottawa, ON, Canada, May 2004 (cancer)
Richard E. Cale (LM1101)
Riverside, Calif., July 2004
Robert W. Sweginnis (MO2039)
Prescott, Ariz., August 2004 (aircraft accident)
Cdr. Lester L. Pierce (LM0917)
Bayside, Calif., 2004
Lt. Col. Andre Goosen (M03969)
Pretoria, South Africa, 2004

Kay Yong Receives Coveted Barbour Award

Dr. Kay Yong, the chairman of the Aviation Safety Council (ASC), Taiwan, was honored with an award for his achievements. Upon the recommendation of the U.S.-based Flight Safety Foundation, Yong received the Laura Taber Barbour Air Safety Award in Shanghai, where the Foundation held its annual international air safety seminar last November.

The Award was established in 1956 by the late Clifford E. Barbour and his son, Clifford E. Barbour Jr., in memory of the elder Barbour's wife, a passenger on a DC-3 that struck a mountain in West Virginia in 1945. The Award recognizes notable achievements in the field of aviation safety in method, design, invention, study, or other improvements. Over the past 48 years, most of the recipients of the Award have been Americans. The Flight Safety Foundation recommended Yong because under his leadership, the ASC has become an independent and professional body, projecting an image of fairness, integrity, and professionalism.

2004 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 35th International Semina*r, held in the Gold Coast, Queensland, Australia, Aug. 30-Sept. 2, 2004, by downloading the information from the appropriate section of the ISASI website 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 2004* 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.

The following papers were presented at ISASI 2004:

Welcome to Australia [Opening Speech] *By Bruce Byron, Chief Executive Officer, Civil Aviation Safety Authority, Australia*

SESSION 1

Aviation Investigation in Australia: Sex, Drugs, Rock 'n Roll, and the Law *By Kym Bills, Executive Director, Australian Transport Safety Bureau*

Investigate, Communicate, Educate: Are We Doing All Three with the Same Energy? *By Réal Levasseur, Transportation Safety Board of Canada*

Past, Current, and Future Accident Rates: Achieving the Next Breakthrough in Accident Rates *By Dr. Robert Matthews, Federal Aviation Administration, U.S.A*

SESSION 2

New Opportunities and New Boundaries: Accident Investigations Involving Engine Consortiums and Alliances *By Michael Bartron and Mike Gamlin, Pratt and Whitney, U.S.A., and Rolls-Royce plc, U.K.*

Airborne Collision Avoidance System: ACAS/TCAS from the Accident Investigation's Point of View *By Johann Reuss, Bundesstelle für Flugunfalluntersuchung (German Federal Bureau of Aircraft Accidents Investigation)*

SESSION 3

The Role of Lessons Learned in the Investigate, Communicate, Educate Cycle for Commercial Aviation *By Dr. Paul Werner and Richard Perry, Sandia National Laboratories, U.S.A.*

Underwater Recovery Operation off Sharm el-Sheikh *By Olivier Ferrante and Jean-Claude Vital, Bureau d'Enquêtes et d'Analyses, France*

SESSION 4

ISASI 2004 Theme *By Rob Lee, International Consultant on Human Factors*

Latent Failures in the Hangar: Uncovering Organizational Deficiencies in Maintenance Operations [Invited Paper] *By Dr. Alan Hobbs, SJSU/NASA-Ames Research Center, U.S.A.*

Equipment Damage and Human Injury on the Apron—Is It the Cost of Doing Business? *By Bob Vandel, Flight Safety Foundation, U.S.A.*

The ATSB Ansett Class A Investigation *By Richard Batt, Lawrie Brown, Suzanne Garniss, Mike Watson, and Julian Walsh, Australian Transport Safety Bureau*

SESSION 5

Juridical and Technical Aspects in the Investigation of Aviation Accidents and Incidents in Argentina and Latin America *By Com. Luis Ortiz and Dr. Griselda Capaldo, Argentine Air Force and Universidad Nacional de Buenos Aires, Argentina*

The Protection of the Sources of Safety Information *By James Burin, Flight Safety Foundation, U.S.A.*

A300B4 Loss of All Hydraulics, Baghdad: A Remarkable Example of Airmanship *By Yannick Malinge, Airbus Industrie, France*

SESSION 6

When an Aircraft Crash Is Not an Accident: Experiences of an Air Safety Investigator at Ground Zero *By Eric West, Federal Aviation Administration, U.S.A.*

The Size of the Aircraft Doesn't Matter *By Lorenda Ward, National Transportation Safety Board, U.S.A.*

Investigation of Fatal Double Engine Flame-out to Shorts SD 360 Turboprop *By Peter Coombs, Air Accidents Investigation Branch, U.K.*

SESSION 7

Field Investigation of the Accident Involving an Ilyushin IL-76 Transport Aircraft in East Timor *By S. Barter, L. Molent, P. Robertson, S. Thompson, G. Fox, and G. Kimmins, Defense Science and Technology Organization, Australian Transport Safety Bureau, and Directorate of Flying Safety ADF, Australia*

WYSIWYG—Or Is It? *By Corey Stephens and Chris Baum, Air Line Pilots Association, International, U.S.A.*

Flight Data Analysis Using Limited Data Sets *By Neil Campbell, Australian Transport Safety Bureau*

SESSION 8

Managing Fatigue as an Integral Part of a Fatigue Risk Management System [Invited Paper] *By Professor Drew Dawson and Kirsty McCullough, Director, Center for Sleep Research, University of South Australia, and Research Student, Center for Sleep Research, University of South Australia*

HFACS Analysis of Military and Civilian Aviation Accidents: A North American Comparison *By Dr. Scott Shappell and Dr. Doug Wiegmann, Civil Aerospace Medical Institute and University of Illinois at Urbana-Champaign, U.S.A.*

SESSION 9

Who Moved My (Swiss) Cheese? The (R)Evolution of Transport Safety Investigation B*y Dr. Steven Shorrock, Mark Young, Capt. John Faulkner, and Graham Braithwaite, the University of NSW, Australia, and Cranfield University, U.K.*

Analysis of Aircraft Propulsion System Failure *By Dr. Arjen Romeyn, Australian Transport Safety Bureau*

The Myth of the Unstable Approach *By Dr. Ed Wischmeyer, Embry-Riddle Aeronautical University, U.S.A.*

SESSION 10

Human Factors in Stressful Team Situations: A View from an Operational and Training Perspective *By Werner Naef, Air New Zealand*

Maintaining an Aircraft Accident Investigation Capability in a Small Military Aviation Organization *By WGCDR Peter Wood, Directorate of Flying Safety, Australian Defense Force*

The Use of Full-Flight Simulators for Accident Investigation *By Robin Tydeman, Air Accidents Investigation Branch, U.K.*

SESSION 11

Air Safety Investigation in the Information Age *By Dr. Robert Crispin, Embraer, Brazil*

Using Physical Evidence from More Complex Mid-air Collisions *By Gijsbert Vogelaar and Keith McGuire, Dutch Transport Safety Board, the Netherlands, and National Transportation Safety Board, U.S.A.*

Reinventing (with Wheels, Wings, and Sails)—A New Look at Transport Accident Investigator Training *By Dr. Graham Braithwaite, Cranfield University, U.K.*

Facts and Lessons Learned from the CI611 Accident Investigation (Text not available) *By Dr. Kay Yong, Aviation Safety Council, Taiwan*

ISASI 2004 Pictorial Review *Photos by Esperison Martinez*


E. MARTINEZ, EDITOR

Johann Reuss, German Bureau of Aircraft Investigations, receives corporate member plaque from ISASI President Frank Del Gandio during ISASI 2004 ceremonies.

Chairman Yong was the *Aviation Weekly and Space Technology* 2002 laureate and also holds the Sir Barnes Wallis Medal, awarded by the Guild of Air Pilots and Air Navigators of Great Britain. Yong, 63, served as adjunct professor of National Cheng Kung University and director of the Aerospace Science and Technology Research Center before he became the ASC managing director and chairman. The Award not only recognizes Chairman Yong's performance but also compliments ASC's overall professionalism. ◆

Who Is Where?

• **Curt Lewis**, ISASI and American Airlines System and Flight Safety, has elected to take an early retirement after 17 years with the airline. He intends to begin a new venture, forming an aviation safety consulting firm that will allow him to draw on his 30 years' experience in the aviation industry. Additionally, he will continue his role as an adjunct professor for Embry-Riddle Aeronautical University, teaching aviation/system safety and accident investigation. He will also continue his affiliation with ISASI where he serves as president of the ISASI U.S. Society, U.S. Councillor, and president of the Dallas/Fort Worth Regional Chapter. His popular electronic flight safety information news service will continue as will his *FSI Quarterly Journal*. He has established new websites: www.curt-lewis.com and www.lewis-engineering.com

• **Dr. William B. Johnson** (MO2301) has accepted the position of chief scientific and technical advisor for human factors in maintenance systems for the Federal Aviation Administration. This newly created position is indicative of an FAA effort to reinvigorate the commitment to human factors as related to maintenance. In the past few years, Transport Canada and the European Aviation Safety Agency have passed rules regarding human factors in maintenance. The rules affect initial certification as well as recurrent training. While the FAA has been a leader in human factors research and development, thus far there are no rules addressing this topic for maintenance personnel.

• **American Eagle** has appointed Capt. Jim Winkley as vice-president of safety for the airline, effective Dec. 17, 2004. In his new role, Winkley will have responsibility for the carrier's flight and ground safety programs, maintenance safety and compliance, regulatory affairs, and dangerous goods program. ◆

NTSB Updates "Most Wanted" Safety Improvements

The National Transportation Safety Board in early November 2004 updated its list of Most Wanted Safety Improvements, noting instances where federal agencies had given unacceptable responses to NTSB recommendations or were moving too slowly to implement recommended safety measures.

Established in 1990, the Most Wanted list is a way for the NTSB to focus attention on needed safety improvements in all modes of transportation. The list


E. MARTINEZ, EDITOR

Itzhak Razcik, Israel Ministry of Transport, accepts ISASI corporate membership plaque during ISASI 2004 ceremonies from President Frank Del Gandio.

highlights recommendations that the Board believes would significantly reduce deaths and injuries. It is updated annually. Listed improvements affecting aviation include

Runway incursions—The Board's recommendation calls for a system that ensures safe movement of airplanes on the ground and provides warnings of probable collisions/incursions directly to flight crews in the cockpit. Status: The Board changed the classification of the Federal Aviation Administration's (FAA) response to this recommendation from "Open-Acceptable Response" to "Open-Unacceptable Response."

Fuel/Air Vapors in Fuel Tanks—Recommendations call for interim measures to reduce flammable fuel/air vapors in fuel tanks and in the longer term airplane design changes to eliminate the generation of such vapors. Status: Due to the lack of FAA initiatives on interim measures, the Board decided to reclassify the short-term recommendation

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from "Open-Acceptable Response" to "Open-Unacceptable Response." On the longer-term recommendation, the Board found the FAA's response acceptable. The Board is anticipating that the FAA will begin the regulatory process to require a flammability reduction system in the near future. Overall, the Board noted that implementation was progressing too slowly.

Aircraft Icing—To reduce the dangers of flying in icing conditions, NTSB recommendations call for expedited research and upgraded airplane design and certification standards. Status: Noting that the oldest icing recommendations on the list date back 8 years, the Board changed the classification of this issue from "Open-Acceptable Response," but progressing slowly, to "Open-Unacceptable Response" based on the FAA's lack of progress in this area.

Child Restraints—Recommendation asks for a requirement that infants and toddlers under age two be safely restrained on takeoff, landing, and in turbulence. Status: "Unacceptable Response" from FAA. ◆

EASA's Continuing Airworthiness Responsibilities

(The following is an excerpt from an incident report issued in the U.K. that Ira Rimson [WO0851] believes it to be of significance to investigators because of the possible loss of information relating to airworthiness, design, and maintenance issues.—Editor)

On Sept. 28, 2003, responsibility for the airworthiness standards for most of the civil aircraft registered in the Member States of the European Union (EU) passed to the European Aviation Safety Agency (EASA). This organization has allocated the responsibility for the continuing airworthiness of non-EU built aircraft to the national airworthiness authorities of the various Member States.

The shift in overall control of airworthiness from national authorities to a federal system has resulted in most national mandatory items (NMIs) generated by the Member States being cancelled effective Sept. 28, 2003. NMIs consist of AADSs together with additional requirements for import (ARIs) and airworthiness notices (ANs). Prior to Sept. 28, 2003, there were more than 3,500 NMIs generated by the U.K., of which the majority were AADs.

Foreign (with respect to the U.K.) airworthiness directives are published by the CAA in CAP 473 (applicable to products and equipment of USA design) and CAP 474 (applicable to products and equipment of non-USA design). The following is an extract from the CAA's description of the changes to these publications that necessarily resulted from the transfer of responsibility to EASA: "The EASA policy for design standards is to adopt the Joint Aviation Authorities (JAA) type certification basis where one exists, and for all other products, the certification basis of the state of design, together with the airworthiness directives issued by the state of design. The European Commission (EC) working group that developed the policy recognized that assessments made and experience gained by EU Member States had led those states to issue airworthiness directives."

Accordingly, the working group recommended that EASA should conduct a review of all products to determine whether the EASA reference type certificates need to be updated for safety reasons by issuing EASA airworthiness directives that have the same effect as those issued previously by Member States. To support EASA in this activity, the CAA has conducted a comprehensive review of the U.K. additional airworthiness directives to identify whether there are particular requirements that should be recommended to EASA for adoption across the EU. Having identified the particular requirements to be recommended to EASA for adoption, the CAA continues to apply these requirements in the U.K. under Article 10(1) of Regulation (EC) 1592/2002.

Under the provisions of Article 10, the European Commission will decide, at some point in the future, whether each requirement should be adopted or not, and will then advise the CAA to retain, amend, or revoke those requirements. Note: Article 10(1) of EC Regulation 1592/2002 makes a provision that "[requirements]...shall not prevent a Member State from reacting immediately to a safety problem which involves a product, person, or organization subject to the provisions of this Regulation." The U.K. CAA was the only authority of the Member States to retain any NMIs under the provisions of Article 10; these amounted to approximately 170, mostly AADs. Most of the AADs within the EU had originated from the U.K. CAA; there would thus be a significant burden placed on the other Member States if they were required by EASA to implement them. This provided the rationale for the CAA review referred to above, in which they had to justify all those AADs they proposed to retain. However, since the final decision will be taken by EASA, there is no guarantee that any of them will ultimately be retained. This effectively underscores the EASA policy of placing greater reliance for continued airworthiness on the states of design, which will continue to issue airworthiness directives. The permanently cancelled AADs included 016-02-80, with the result that maintenance organizations are no longer required to comply with it. ◆

NEW MEMBERS

Corporate

Military Airworthiness Authority, CP0226
Nicholas P. McNulty
Thomas G. Claffey
MyTravel Airways, CP0227
Chris White
Phil Oakes
Dutch Airline Pilots Association, CP0228
Leonardus Hartman
Rutger Vossen

Individual

Apeagyei, Frederick, B., AO5109, Accra, Ghana, West Africa
Bell, Stephen, G., FO5100, Onisholm, ACT, Australia
Bramble, Jr., William, J., MO5122, Washington, DC, USA
Cauthen, Matthew, S., ST5108, Daytona Beach, FL, USA
Dacier, Matthew, S., ST5097, Hampton, NH, USA
Debono, Daniel, J., ST5096, Palmerston North, New Zealand
Fruchter, Marc, A., AO5118, Landrum, SC, USA
Guitz, Amiel, J., MO5094, Haysville, KS, USA
Hendrickson, Robert, P., AO5114, South Portland, MI, USA
Hung, Jonathan, ST5120, Singapore, Singapore
Kirk, James, K., AO5115, Chicago, IL, USA
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Li, Yong, FO5111, Beijing, China (P.R.C.)
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CAAC to Tighten Control On Flight Safety

The nation's civil aviation watchdog vowed in the closing days of 2004 to develop tighter controls to ensure safer flights, according to China Daily. Safety supervision will top the Administration's efforts during 2005 as potentially dangerous problems still lurk in the industry, said Yang Yuanyuan, director of the General Administration of Civil Aviation of China (CAAC). Yang made the remarks at a 2-day national conference held in Beijing.

While intensifying liability for aviation enterprises, the Administration plans to launch intensive checks of flight training and aircraft maintenance as well as overtime flights, he said. Since the reforms in the civil aviation industry were completed in July, discrepancies have been found in some companies' operations and technical standards as well as flight controls and management.

"The Administration and regional aviation authorities will conduct an assessment of airports' maintenance capabilities. Those that fail to meet the requirements will be forced out of the market," Yang said. He urged airlines to intensify construction of operation control centers to improve the efficiency in plane deployment. "At the same time, airlines must increase input into training of flight and maintenance professionals to improve their ability to ensure safety," Yang said.

In his annual report, Yang highlighted safety concerns that have grown since a China Eastern plane crashed in North China's Inner Mongolia Autonomous Region on November 21, killing 55. The accident brought to an end the safest period in the nation's civil aviation history—5 million flying hours in 30 months without accidents since May 8, 2002.

According to CAAC's statistics, from January to November, the passenger transport capacity totaled more than 112 million while cargo transport hit 2.5 million tons, that's up 41.5 and 26.7%, respectively, from a year earlier.

To promote safety management, Yang said his Administration will formulate a system in the next year to demand airlines earmark capital for safety training, purchase of facilities for emergency rescue operation, and assessment of potential danger for accidents. The CAAC will regulate how much they should devote to this effort. ◆

E. MARTINEZ, EDITOR

BEA's Martine Del Bono, and attending representatives, accepts corporate membership plaque during ISASI 2004 ceremonies from President Del Gandio.

CASA Report Shows Falling Accident Rate

Australia's light aircraft accident rate has continued to fall steadily by more than 4% each year over the last 10 years. At the same time, the accident rate over the last decade for large regular public-transport aircraft has averaged just 0.2 for every 100,000 hours of flying, according to the country's Civil Aviation Safety Authority (CASA).

Low-capacity regular public-transport aircraft have an accident rate of 1.1 per 100,000 hours of flying. The accident rate figures are featured in the latest annual report issued by CASA. Figures show that over the last decade there have been no fatal accidents in Australia involving high-capacity regular public-transport aircraft.

Over this time, fatal accidents in light aircraft have been falling each year by 5.7%. CASA's chief executive officer, Bruce Byron, said while the improving accident rate is good news, more work must be done to address aviation risks. Byron said CASA has begun a special review of the aviation system to identify the major risks to air safety in each sector of aviation. He said he is also acting to ensure CASA's inspectors spend more time in the field working with people in the aviation industry. "CASA is focusing more on helping the industry comply with aviation safety requirements.

"We see the way ahead as a willing partnership in safety between CASA and members of the aviation industry who, at the end of the day, have a duty of care to deliver operational safety." ◆

Latent Failures in the Hangar *(from page 13)*

naire has been completed by a sample of maintenance personnel, the ratings are combined to create a profile similar to the example shown in Figure 2 *(page 13)*.

Auto-maintain?

Advances in technology throughout the last century have enabled the number of flightcrew members to be progressively reduced to the standard complement of two on current aircraft. Developments in UAV technology have already led to unmanned combat aircraft. Unmanned civilian cargo aircraft may be in service before long.

Despite continuing advances in vehicle health monitoring and built-in test equipment, the work of maintenance personnel is unlikely to be automated in the near future because maintenance activities present challenges that, at present, only humans can meet. We may be able to auto-fly but we cannot "auto-maintain."

In order to understand maintenance deficiencies and the conditions that lead to them, it is necessary to appreciate the demands that maintenance work places on the individual maintenance worker, and the types of errors and violations that occur in response to these demands. Memory lapses, procedural non-compliance, and knowledge-based errors are significant classes of unsafe acts in maintenance.

Some of the conditions that promote errors and violations in maintenance have been clearly identified in recent years. For example, fatigue and time pressure are widely recognized hazards. In these cases, policies regulating hours of work and maintenance resource management (MRM) training are potentially effective countermeasures, as in ICAO's *Human Factors Guidelines for Aircraft Maintenance*.

Other threats to maintenance quality are harder to identify. These include recurring errors, traps in procedures, and practices that introduce unacceptable iatrogenic risks. The potential for delay between maintenance actions and consequences can present a problem for reactive investigations. The blame culture that pervades much of the industry can make it difficult to proactively identify threats to maintenance quality. One of the most pressing challenges now facing the maintenance sector is not technical in nature; rather, it is how to foster a spirit of glasnost to promote incident reporting and the disclosure of incident information. ◆

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The Norwegian Accident Investigation Board

(Who's Who is a brief profile of an ISASI corporate member to enable a more thorough understanding of the organization's role and function.—Editor)

The history of the Norwegian Accident Investigation Board (AIBN) began in 1923 when Norway enacted its first Air Navigation Act. Until 1989 the Board's investigating of aviation accidents and incidents was established on an ad hoc basis. In 1989 a new act was passed that established the Board as a permanent and independent agency within the Ministry of Transport and Communications. On July 1, 2002, the scope of the Board was widened to also encompass railway accidents and incidents. Beginning in the summer of 2005, the Board will also be responsible for investigating road accidents, and in the winter of 2006 marine accident investigation will be included.

The objectives of the Board's investigations are to expose the probable cause of events of civil aircraft accidents and serious incidents within Norway. The fundamental purpose of the AIBN is to improve aviation safety by determining the causes of air accidents and serious incidents and making safety recommendations intended to prevent recurrence. It is not to apportion blame or liability. To achieve confidence from the public regarding the transportation accident investigation process, it is essential that the Board be independent and free from any conflicts of interest when investigating accidents and identifying safety deficiencies.

For aviation accidents, delegates of the AIBN may participate as Norwegian accredited representatives in investigations carried out in other States where Norwegian passengers or Norwegian-registered aircraft or vehicles are involved. Norway may also support other nations' investigation boards with investigating expertise when needed.

The aviation division of the Board consists of eight specialists within aviation, covering both heavy and light aircraft and helicopters. The background of the specialists ranges from pilots, engineers, and air traffic controllers to human factors. The Board manages most of the investigations with in-house expertise but has the opportunity to call upon other experts when required. The investigators-in-charge also have the capability to get support from assistant investigators assigned to the Board who have long-term experience.

Accident Investigation Board Norway HSLB

Within 12 months after the accident or incident a written report is made available in print or on the Internet. The final report contains a description of the course of events, the fact-finding phase, the accident investigation process, the analysis of the factual findings, and a specification of the methods used in addition to the safety recommendations. Before being made public, the report is coordinated with the parties involved and the public authorities affected. This process takes 3 weeks for national accidents and 60 days for international accidents.

The AIBN has, among other accidents, been in charge of investigating the Partnair accident, in which a Convair 580 aircraft broke up in the air during cruise above the Norwegian sea and 55 people were killed. Most of the debris was retrieved from the bottom of the sea. The Board was also in charge of the investigation of a Russian Tupolev after it hit the top of a mountain near Svalbard Airport in 1996 and 146 people died.

At present, the aviation division of the AIBN is investigating 15 accidents and approximately 100 incidents, including air traffic control incidents. (For more information, visit www.aibn.no.) ◆

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