ISASI FORUM

"Air Safety Through Investigation"

JULY–SEPTEMBER 2010

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On Sept. 27, 2008, at 2358, EDT, an Aerospatiale (Eurocopter) AS365N1 helicopter, operated by the Maryland State Police as a public-use medical evacuation flight, collided with trees and terrain in District Heights, Md. The flight had been cleared by ATC for an ILS approach to Andrews AFB, Camp Springs, Md. Instrument meteorological conditions prevailed at the time of the accident. Four persons died; one survived the crash. The flight originated from Waldorf, Md. destined for the Prince George's County Hospital (PG), Cheverly, Md. (Photo: NTSB Public Docket)

ISASI FORUM
"Air Safety Through Investigation"

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AIR SAFETY INVESTIGATORS
INCORPORATED AUGUST 31, 1964

ISASI Bolsters Domestic and International Exposure

By Frank Del Gandio, ISASI President

For perhaps the first time, the European, Australia, New Zealand, and the U.S. Societies have conducted seminars in the same calendar year. The Canadian Society teamed up with the Air Canada Pilots Association and held one last October, The Asian Society was formed, and, of course, ISASI 2010 in Sapporo, Japan, will happen in September. This means that in the course of just more than 12 months, ISASI-related groups have conducted or co-sponsored safety seminars in Europe, Canada, the U.S., Asia, Australia, and New Zealand. And when you add the effects of the Reachout Workshop program, it measures as quite an accomplishment.

For a considerable period of time, only the Australian and New Zealand Societies combined their efforts in an annual seminar. This, coupled with the annual ISASI international seminar, constituted ISASI's exposure through large group events.

Australian Society President Lindsay Naylor noted that of late the new members drawn to the joint seminar come from "the younger generation." So as older member leave the scene, the membership base becomes a bit more youthful. He adds that the "Y" generation brings with it a questioning attitude about traditional issues and responses. "It's all to the good," says Lindsay, "keeps the activities fresh."

Then in 2008 the European Society reactivated its program and conducted a European seminar that drew more than 100 persons to a 2-day event. In June, that Society completed its third consecutive seminar. In all, the Society has drawn close to 300 safety advocates to its seminars. Dave King, European Society president, said of his seminars: "The goal in 2008 was to present a compact, high-quality technical program with low associated cost overheads to make the seminar affordable to delegates in a time of increasing financial constraint. This has been achieved with the help of generous corporate support in the donation of presentation venues and other logistical support. The outcome has been an attendance representing a broad spectrum of practitioners and managers, many of whom could not get sponsorship to attend the ISASI seminar, stimulating debate around topics of direct challenge to the current-day investigator and industry from a European perspective. We have other States registering an interest in hosting future events and an enthusiastic delegate base so we look to build on the program."

In October of last year, the Canadian Society co-hosted an International Winter Operations Conference held in Ontario, Canada. It drew more than 200 attendees, from 13 countries, who listened to airport operators, weather forecasters, fire and rescue experts, airline and aircraft manufacturers, and safety regulators discuss contaminated runways, airframe, and engine icing, and the full range of activities encountered in winter operations. Barbara Dunn, president of the Canadian Society, noted that the event permitted ISASI to gain a bit more exposure than otherwise would have occurred and gave the many attending Canadian Society members a chance to interact with international peers, which she labeled as a big plus.

The U.S. Society, directed by Toby Carroll, conducted its first seminar in June with more than 100 persons attending. The 2-day event included three breakout sessions: general aviation, commercial aviation, and helicopter operations. Carroll described the event's impact this way: "The organizing committee was pleased to provide an additional and complimentary venue to chapter meetings and annual international seminars for U.S. Society members. We had more than 30 attendees submit membership applications and were able to reach a significant number of individuals who are not able to come to international seminars. It was also encouraging to have a good turnout of the next generation of air safety investigators."

For perhaps the first time, the European, Australia, New Zealand, and the U.S. Societies have conducted seminars in the same calendar year.… This means that in the course of just more than 12 months, ISASI-related groups have conducted or co-sponsored safety seminars in Europe, Canada, the U.S., Asia, Australia, and New Zealand. And when you add the effects of the Reachout Workshop program, it measures as quite an accomplishment.

The Society's annual international seminar has continually attracted high numbers of attendees from a considerable number of countries. For example, ISASI 2009 drew 215 delegates from 33 nations, and 2008 drew 284 from 34 countries. This year's event in Sapporo, Japan, is expected to again be a magnet for those in the accident investigation profession as well as other aviation specialties.

A measure of ISASI's extended presence can be seen in the development of AsiaSASI, whose formation gained ISASI's international council approval last September. The new Society's birthright reaches back to ISASI 2007, held in Singapore. It was there that many ISASI Asian members who regularly attend the annual event surfaced the idea of forming AsiaSASI. Two years in the making and with many consultations with Caj Frostell, ISASI international councillor, the Asian society became a reality. All ISASI members in Asia automatically

ISASI 2010 SAPPORO, JAPAN

The International Society of Air Safety Investigators (ISASI) will hold its 41st annual international seminar (ISASI 2010) in Sapporo, Japan, from Sept. 6-9, 2010. The Japan Transport Safety Board (JTSB) will host ISASI 2010, and we expect attendance of more than 300 representatives from government and industry from around the world. The seminar theme is **"Investigating ASIA in Mind—Accurate, Speedy, Independent, and Authentic,"** with a sub-theme of **"Over Cultural Differences and Language Barriers."**

The main seminar program will be held September 7-9 with two tutorials being conducted on September 6. Tutorial No. 1 is entitled **"Investigating Human Factors: The Human/Machine Interface"** and Tutorial No. 2 is entitled **"Aircraft Numbers Are Increasing Worldwide. How Do We Prevent Accidents?"**

Please make your seminar registration and hotel reservation arrangements through the seminar website at http://www2.convention.co.jp/isasi2010/index.html or use the link from the ISASI website at www.isasi.org.

Sponsorship and exhibitor opportunities are available during the course of the seminar.

If you have any questions, please feel free to contact any of the following:

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We look forward to seeing all of you in Sapporo.

became members of AsiaSASI. It has 18 corporate members and its officers are organizations rather than individuals (see *ISASI Forum*, October–December 2009, page 26). AsiaSASI spokesman Chan Wing Keong noted: "This Asian regional society of ISASI was established to promote aviation safety and strengthen the cooperation between aircraft accident investigation bodies within the region…. [We] believe that the AsiaSASI will serve as a regional cooperation forum linking aircraft accident investigators in Asia and making contributions to the international community."

But by far, ISASI'S most grassroots-directed activity is its Reachout Workshop program, which provides accident investigation and safety management tools and procedures to any group that feels it can enhance its investigation processes through the program. Initiated in 1999, it has taken its teaching tools to 36 workshops and has taught more than 1,900 persons in 21 countries in the following areas: Africa (1), Asia (11), Middle East (10), Europe (5), Australia (4), Americas (5—South, Central, the U.S.). ISASI receives no income from this program. Except for seed funding, its operation and success is owed to groups that recognize the impact the program may have on the organization and that sponsor the training. John Guselli, chairman of the Reachout program, noted that the program "continues to maintain substantial resources in a multitude of air safety related domains serviced by a register of expert ISASI volunteers…geographically dispersed around the world." He added, "[We] continue to explore additional means of supporting organizations…."

Unquestionably, ISASI's "internationalization" is not the result of any single event; it is all our activities combined that works in this direction. Caj Frostell expressed this best with his recollection that "We held a number of Reachouts in Asia, which set the stage for ISASI 2007 held in Singapore, leading to the formation of AsiaSASI." Caj was also heavily involved in the Reachouts held in the Middle East, which he said has created "ISASI faces" in that part of the world. But his most telling observation regarding ISASI's increased exposure is that "ISASI's contribution to international aviation safety is well regarded within ICAO. This is evidenced by ISASI being invited as a recognized observer organization to participate in the ICAO Divisional Meetings in 1992, 1999, and 2008. At the 2008 meeting, we made a significant contribution to the AIG/2008 meeting (see *ISASI Forum,* January–March 2009, page 4).

There can be no doubt that the combined activities of our societies and groups have greatly extended ISASI presence in both the domain of each society and in the international realm of air accident investigation. ISASI members have much to be proud of, and a great deal of it is owed to themselves and the support they give to their Society's activities and efforts. ◆

USING HET TAXONOMY TO HELP STOP HUMAN ERROR

Research results will help to improve safety when performing a go-around by identifying potential errors on a step-by-step basis and allowing early remedial actions in procedures and crew coordination to be made.

By Wen-Chin Li, Don Harris, Neville A. Stanton, Yueh-Ling Hsu, Danny Chang, Thomas Wang, and Hong-Tsu Young

(This article is adapted with permission from the authors' paper entitled Human Error Prevention: Using the Human Error Template to Analyze Errors in a Large Transport Aircraft for Human Factors Considerations *presented at the ISASI 2009 seminar held in Orlando, Fla., Sept. 14-18, 2009, which carried the theme "Accident Prevention Beyond Investigation." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

Flight crews make positive contributions to the safety of aviation operations. Pilots have to assess continuously changing situations, evaluate potential risks, and make quick decisions. However, even well-trained and experienced pilots make errors. Accident investigations have identified that pilots' performance is influenced significantly by the design of the flightdeck interface. This research applies hierarchical task analysis (HTA) and utilizes the Human Error Template (HET) taxonomy to collect error data from pilots during flight operations when performing a go-around in a large commercial transport aircraft.

HET was originally developed in response to a requirement for formal methods to assess compliance with the new human factors certification rule for large civil aircraft introduced to reduce the incidence of design-induced error on the flight deck (EASA Certification Specification 25.1302). The HET taxonomy was applied to each bottom-level task step in an HTA of the flight task in question. A total of 67 pilots participated in this research, including 12 instructor pilots, 18 ground training instructor, and 37 pilots. Initial results found that participants identified 17 operational steps with between 2 and 8 different operational errors being identified in each step by answering questions based either on his/her own experience or their knowledge of the same mistakes made previously by others. Sixty-five different errors were identified.

While high levels of automation in third-generation airliners have undoubtedly contributed considerable advances in safety over earlier jet transport aircraft, new types of error have emerged on these flight decks. These types of accidents are exemplified in crashes such as the Nagoya Airbus A300-600 (in which the pilots could not disengage the go-around mode after its inadvertent activation; this was as a result of a combination of lack of understanding of the automation and poor design of the operating logic in the autoland system), the Cali Boeing 757 accident (in which the poor interface on the flight management computer and a lack of logic checking resulted in a CFIT accident), and the Strasbourg A320 accident (in which the crew inadvertently set an excessive rate of descent instead of manipulating the flight path angle as a result of both functions utilizing a common control interface and an associated poor display). Human error is now the principal threat to flight safety. A 1998 Civil Aviation Authority worldwide survey of causal factors in commercial aviation accidents determined that in 88% of cases the crew was identified as a causal factor; in 76% of instances, the crew was implicated as the primary causal factor.

The pilot of a modern commercial aircraft is now a manager of the flight crew and of complex, highly automated aircraft systems. The correct application of complex procedures to manage activities on the flight deck is now an essential part of ensuring flight safety. While pilot error is now the major contributory factor in aircraft accidents, a diagnosis of "error" in itself says very little. It is not an explanation; it is merely the beginning of an explanation. As S.W.A. Dekker proposed in his 2001 article, 'The Re-Invention of Human Error," errors are systematically connected to many features of a pilot's tools and tasks and that the notion of error itself has its roots in the surrounding

Wen-Chin Li

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socio-technical system associated with aircraft operations. The question of human error or system failure alone is an oversimplification. The causes of error are many and varied and almost always involve a complex interaction among the pilot's actions, the aircraft flight deck, the procedures to be employed, and the operating environment.

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

Perhaps the true significance of the establishment of this regulation is that for the first time there is a specific regulatory requirement for "good" human factors on the flight deck. It is an attempt to eradicate many aspects of pilot error at the source.

HET has been demonstrated to be a reliable and valid methodology. It has been benchmarked against three existing techniques: SHERPA—Systematic Human Error Reduction and Prediction Approach; Human Error HAZOP—Hazard and Operability study; and HEIST—Human Error In Systems Tool, and outperformed all of them in a validation study

However, such rules relating to design can only address the fabric of the airframe and its systems; the new regulations can only minimize the likelihood of error as a result of poor interface design. The new regulations cannot consider errors resulting from such factors as the inappropriate implementation of procedures, etc.

From a human factors viewpoint, which assumes that the root causes of human error are often many and interrelated, the new regulations have only addressed one component of the wider problem. The design of the flightdeck interfaces cannot be separated from the aircraft's operating procedures. Complex flightdeck interfaces, while potentially more flexible, are also potentially more error prone (there are far more opportunities for error). Analysis of aircraft accident investigation reports has suggested that inappropriate system design, incompatible cockpit display layout, and unsuitable standard operating procedures (SOPs) are major factors causing accidents.

Checklists and procedures

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

Formal error identification techniques implicitly consider simultaneously both the design of the flightdeck interfaces and the procedures required to operate them. They can be applied at early design stages to help avoid design-induced error during the flightdeck design process, but they can also be used subsequently during flight operations to diagnose problems with SOPs and provide a basis for well-founded revisions. However, it should be noted that formal error prediction methodologies only really address Reason's skill-based (and some rule-based) errors within a fairly well-defined, proceduralized context. Hence they can only help in protecting against errors that relate either to the flightdeck interfaces or their associated operating procedures.

HET, developed by A. Marshall, N. Stanton, M. Young, P. Salmon, D. Harris, J. Demagalski, T. Waldmann, and S. Dekker is a human error identification (HEI) technique designed specifically for application on the aircraft flight deck. Advisory Circular AC25.1309-1A suggested that the reliable quantitative estimation of the probability of crew error was not possible. As a result, HET was developed specifically for the identification of potential errors using formal methods, not their quantification. It was developed as a diagnostic tool intended as an aid for the early identification of design-induced errors, and as a formal method to demonstrate the inclusion of human factors issues in the design and certification

Error Modes / Sub-task for performing Go-around by HTA		Fail to execute	Task execution incomplete	Task executed in wrong direction	Wrong task executed	Task repeated	Task executed on wrong interface element	Task executed too early	Task executed too late	Task executed too much	Task executed too little	Misread information	Other
1.1.1	Press TO/GA Switches	33.93	16.07	7.34	26.79	16.07	7.34	16.07	25.00	1.79	0.00	1.79	3.57
1.1.2	Thrust has advanced	26.79	48.21	0.00	0.00	0.00	0.00	5.36	5.36	10.71	0.00	5.36	8.93
1.2.1	PF command flap 20	42.86	12.50	0.00	5.36	0.00	0.00	3.57	42.86	1.79	1.79	0.00	0.00
1.2.2	PM place flap lever to 20	19.64	14.29	10.71	5.36	0.00	3.57	5.36	19.64	3.57	0.00	0.00	7.14
1.3.1	Verify TO/GA mode annunciation	48.21	26.79	1.79	1.79	0.00	5.36	0.00	8.93	0.00	1.79	12.50	7.14
1.3.2	Rotate to proper pitch attitude	5.36	39.29	3.57	1.79	1.79	0.00	5.36	25.00	35.71	8.93	3.57	1.79
1.4.1	Verify adequate thrust for go-around	53.57	39.29	7.14	5.36	0.00	0.00	3.57	8.93	1.79	3.57	10.71	3.57
1.4.2	Announce go-around thrust set	62.50	26.79	0.00	1.79	0.00	0.00	1.79	12.50	0.00	3.57	0.00	0.00
1.5.1	Verify positive rate of climb	32.14	19.64	7.14	0.00	0.00	0.00	1.79	23.21	0.00	0.00	0.00	12.50
1.5.2	Place gear lever to up	39.29	7.14	5.36	3.57	0.00	1.79	19.64	42.86	0.00	0.00	0.00	8.93
1.6.1	Select Roll mode	26.79	14.29	14.29	10.71	0.00	8.93	5.36	51.79	0.00	0.00	3.57	3.57
1.6.2	Verify Roll mode annunciation	35.71	23.21	1.79	3.57	0.00	0.00	0.00	17.86	0.00	3.57	3.57	8.93
1.6.3	Turn into correct track	5.36	28.57	10.71	5.36	0.00	1.79	5.36	41.07	3.57	0.00	0.00	3.57
1.7.1	Select Pitch mode	23.21	26.79	23.21	5.36	0.00	3.57	8.93	50.00	1.79	1.79	3.57	3.57
1.7.2	Verify Pitch mode annunciation	26.79	26.79	3.57	3.57	0.00	0.00	1.79	21.43	0.00	3.57	0.00	10.71
1.7.3	Maintain proper pitch attitude	12.50	46.43	12.50	1.79	0.00	1.79	1.79	21.43	7.14	8.93	3.57	1.79
1.8	Follow M/A Procedure	10.71	50.00	25.00	17.86	0.00	7.14	8.93	30.36	0.00	0.00	12.50	3.57

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

process of aircraft flight decks.

HET has been demonstrated to be a reliable and valid methodology. It has been benchmarked against three existing techniques: SHERPA—Systematic Human Error Reduction and Prediction Approach; Human Error HAZOP—Hazard and Operability study; and HEIST—Human Error In Systems Tool, and outperformed all of them in a validation study comparing predicted errors to actual errors reported during an approach and landing task in a modern, highly automated commercial aircraft. The HET method has been proven to be simple to learn and use, requiring very little training, and is so designed to be a convenient method to apply in a field study. The error taxonomy used is comprehensive as it is based largely on existing error taxonomies from a number of HEI methods, but it has been adapted

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

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

and extended specifically for the aerospace environment.

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

Study method

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

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

Task Decomposition: Go-around operations can be considered as the required actions to be made by a pilot to achieve the associated goal and based on the SOPs. Once the overall task goal (safely performing a go-around) had been specified, the next step was to break this overall goal down into meaningful sub-goals, which together formed the tasks required to achieve the overall goal.

In the task "safely performing a go-around," this overall goal was broken down into sub-goals, for example: 1.1 Press TO/GA Switches, 1.2 Set Flaps Lever to 20, 1.3 Rotate to Go-around Attitude, 1.4 Verify Thrust Increase, 1.5 Gear up, 1.6 Select Roll Mode, 1.7 Select Pitch

Mode, and 1.8 Follow Missed Approach Procedures. The analysis of each task goal was broken down into further sub-goals, and this process continued until an appropriate operation was reached. The bottom level of any branch in a HTA should always be an operation. For example, the sub-goal 1.7 Select Pitch Mode was broken down into the following operations: 1.7.1 Select Pitch Mode, 1.7.2 Verify Pitch Mode Annunciation, and 1.7.3 Maintain Proper Pitch Attitude. Seventeen bottom-level tasks were identified in this analysis.

Classifying Error Modes: HET is a checklist-style approach to error prediction utilizing an error taxonomy comprised of 12 basic error modes. The taxonomy was developed from reported instances of actual pilots and extant error modes used in contemporary HEI methods. The HET taxonomy is applied to each bottom-level task step in an HTA of the flight task in question. The technique requires the analyst to indicate which of the HET error modes are credible (if any) for each task step, based upon their judgment. There are 12 basic HET error modes: "Failure to execute," "Task execution incomplete," "Task executed in the wrong direction," "Wrong task executed," "Task repeated," "Task executed on the wrong interface element," "Task executed too early," "Task executed too late," "Task executed too much," "Task executed too little," "Misread information," and "Others." A full description of the methodology and all materials can be found in Development of the Human Error Template–A New Methodology for Assessing Design Induced Errors on Aircraft Flight Decks (2003) by A. Marshall, N. Stanton, M. Young, P. Salmon, D. Harris, J. Demagalski, T. Waldmann, and S. Dekker.

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

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

Results and discussion

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

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

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

Many of the errors observed during the go-around show an interaction between procedures and the design of the flight deck. They are not simply the product of either poor design or inadequate SOPs alone. For example, the responses to Question 8 (see Table 2) suggested that on many occasions the thrust levers were not advanced manually when the autothrottles became inoperative. There could be several reasons for this. For instance, when a pilot decides to go around, the first step is to press the TO/GA switches, which will activate the correct mode of the autothrust system. However, to control thrust manually, pilots need to press the autothrust disengage switches. Since the TO/GA switches and autothrust disengage switches are next to one another, pilots may accidentally press the wrong switch, which would cause the thrust levers not to advance during the go around.

The following are some incidents related to the sub-task of "Press TO/GA Switches," (1) Pilot retried to push the TO/GA switch immediately, aircraft continued the go-around operation; (2) Pilot failed to press TO/GA switch, aircraft touched down on the runway due to no go-around thrust being delivered and caused a hard landing incident; (3) Aircraft became unstable during approach due to unsuccessful go-around. Aircraft went into incorrect pitch attitude, either below normal flight path or pitched up to high pitch attitude; (4) Flight director (F/D) did not display go-around pitch because of autoflight display system (AFDS) was not triggered; it wouldn't provide correct pitch guidance because pitch mode annunciation did not change to go-around mode. However, the error data also show a failure to follow the required procedures—in this instance Question 23 ("failed to check go-around thrust setting"), which should pick up the failure of the thrust levers to advance to the appropriate setting.

Such confusion of system interface components is not new. Alphose Chapanis in his book *The Chapanis Chronicles* recalls his work in the early 1940s in which he investigated the problem of pilots and copilots retracting the landing gear instead of the landing flaps after landing in the Boeing B-17. His investigations revealed that the toggle switches for the gear and the flaps were both identical and next to each other. He proposed coding solutions to the problem: separate the switches (spatial coding) and/or shape the switches to represent the part they control (shape coding) enabling the pilot to tell either by looking at it or by touching the switch what function it controlled. This was particularly important especially in a stressful situation (for example, after the stresses of a combat mission or in this case, when performing a go-around).

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

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

It is hoped that the implementation of new human factors certification standards and the analysis of associated procedures using a validated formal error prediction methodology will help to ensure that many of these potential errors will be eliminated in the future.

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

Both Reason and Dekker have proposed that human behavior is governed by the interplay between psychological and situational factors. The opportunities for error are created through a complex interaction among the aircraft flightdeck interfaces, system design, the task, the procedures to be employed, and the operating environment. It is naive to assume that simply improving one component (such as the flightdeck interfaces) will have a major effect in reducing error by considering it in isolation.

With regard to the HET methodology employed, prior to this study it has always been used in a prospective manner to predict design-induced error on the flight deck. This study also demonstrates that it can be used in the opposite manner to structure data collection and provide an analytical taxonomy for the retrospective collection of error data. Looking ahead, the HET methodology can also be applied to prospectively test any revised SOPs to assess their error potential prior to instigating them, thereby avoiding the requirement for an error history to develop before the reevaluation of the revised procedures is possible.

Conclusion

By the use of a scientific HTA-based approach to evaluate current SOP's design together with a formal error analysis, and consideration of the interface layout and operating procedures, flight safety will be enhanced and a user-friendly task environment can be achieved. This research used the HET error identification methodology (originally developed to assess design induced error as part of the compliance methodologies under AMC25.1302) in a retrospective manner to assess error potential in existing SOPs when performing a go-around in a large commercial jet transport aircraft. It was found that pilots committed three basic types of error with a high likelihood of occurrence during this maneuver: "Fail to execute," "Task execution incomplete," and "Task executed too late." Many of these errors had roots resident in the design of the procedures or resulted from an interaction between the procedures and some aspects of the flightdeck design. It is hoped that the implementation of new human factors certification standards and the analysis of associated procedures using a validated formal error prediction methodology will help to ensure that many of these potential errors will be eliminated in the future. ◆

(Acknowledgement—This project is supported by the grant from the National Science Council of Taiwan [NSC-98-3114-Y-707-001]. The authors would like to express their appreciation to the Aviation Safety Council for providing a financial endowment to carry out this research.)

Three 'Kapustin' Scholars Selected

Students from Embry-Riddle Aeronautical University, Florida, U.S.A.; Institut Superieur de l'Aeronautique et de l'Espace, Toulouse, France; and Cranfield Safety and Accident Investigation Centre, Cranfield University, UK, have been selected as the 2010 recipients of ISASI's Rudolph Kapustin Memorial Scholarship.

By Esperison Martinez, Editor

Maggie Wai Yee Wong, Embry-Riddle (ERAC); Logan Jones, Institut Superieur de l'Aeronautique et de l'Espace (ISAE); and Leigh Dunn, Cranfield Safety and Accident Investigation Centre, Cranfield University, have been selected by ISASI scholarship fund administrators as 2010 recipients of the ISASI Rudy Kapustin Memorial Scholarship. The Scholarship was established in memory of all ISASI members who have died and was named in honor of the former ISASI Mid-Atlantic Regional Chapter president.

The Scholarship is intended to encourage and assist college-level students interested in the field of aviation safety and aircraft occurrence investigation, according to Richard Stone, ISASI executive advisor and one of the two fund administrators. Contributions such as those made at the recent MARC meeting (see page 26) have and will continue to provide an annual allocation of funds for the Scholarship.

The ISASI executive advisor and ISASI vice-president, offices presently filled by Stone and Ron Schleede, serve as executors and administrators of the fund. They review all applications, which include a 1,000 (+/- 10%) word essay in English addressing the challenges for air safety investigators. The Scholarship consists of an annual $2,000 award, a one-year ISASI membership, and a fee-free attendance at an accident investigation course at both the FAA's Transportation Safety Institute and the Southern California Safety Institute.

The award's intent is to grant a student membership in ISASI and to assist the recipient(s) to attend the respective year's ISASI annual international seminar on air accident investigation. No dues funds are used to support this program. It is totally dependent upon voluntarily (tax free in the U.S.) contributions. Since the program's inception, more than $35,166 have been donated. Much of the funding has come from donations made by ISASI chapters and societies.

Maggie Wong is seeking an undergraduate degree in safety science (aviation). She will graduate in May 2011 from ERAU, Daytona Beach, Fla. She was born in Hong Kong, calls Fayetteville, Ga., her hometown, and presently lives in Daytona Beach. Her interests are varied: art, music, cooking, language, shopping, traveling, and flying.

She says about herself: "I am a college senior who was also the student president for the ISASI student chapter for the academic year 2009 to 2010. Since I was little, I have always enjoyed looking at planes and eventually decided to become a pilot. However, after obtaining my private pilot license in high school, I realized that I would like flying more if I were to do it for recreation. After consulting some professors in the safety field, I decided to begin an education in aviation safety. Not only can I save lives by making changes, but I can also make a difference. Additionally, I can even have a closer look into aircraft. Upon my graduation, I will continue to pursue a career in aviation safety and a masters degree in a related field."

Her professional aspirations? "Making a difference."

Logan Jones is pursuing a Ph.D. in aeronautical science—modeling aircraft takeoff and landing performance on contaminated runways—from ISAE; he is expected to complete his degree in February 2012. His birth place and home is Alberta, Canada; but he resides in Toulouse, France. Jones holds a BSc in mechanical engineering from the University of Alberta, Canada, and an MSc in aeronautical engineering from ISAE in France. He is licensed as a private pilot and enjoys scuba diving, traveling, and soccer.

His intense interest in aeronautics is evident from his undergraduate and graduate studies and accomplishments, which he described in response to a query from the *Forum*. "After receiving my MSc, I accepted to do a thesis in collaboration with ISAE, the French aeronautic research lab Onera, and Airbus. It was the subject of the thesis work and its applications that intrigued me. The subject is to study and model the effects of runway contamination on aircraft take-off and landing performance. By better understanding the effects, we can build better models to calculate the aircraft takeoff and landing distances. The subject intrigued me due to the enormity of the current problem; 30% of all accidents are runway excursions, of which the majority had runway contamination/poor braking as a contributing factor. Therefore, if we can get the pilots better information in the cockpit regarding the runway state and its effect on the aircraft performance, we can vastly improve safety. As part of the thesis work, I have studied several runway overrun accidents and performed numerous aircraft flight performance reconstructions to determine the effects of the runway state. It was this work and my interest in aircraft accidents and safety that led me to ISASI."

His professional aspirations? "To continue to contribute to aeronautical safety. Whether that be on the manufacturer side to continue to innovate aircraft systems to reduce accidents or on the investigative side to explain the cause of accidents and implement measures to reduce the risk of reoccurrence."

Leigh Dunn is pursuing his Ph.D. from the Cranfield Safety and Accident Investigation Centre at Cranfield University, UK. He is researching composite material failure analysis from the field investigator's perspective. Born in the UK, his home is in Hockliffe, UK. He holds a BEng in aerospace engineering from the University of Hertfordshire. He is licensed as a private pilot and flies gliders. Married, he spends his extra time with his 16-month-old daughter and rides a motorbike for recreation.

Here is his response to the

Forum's request for a short biography: "I'm 29 and started flying gliders at the age of 13. At the age of 19, I entered the University of Hertfordshire. While there, I flew in the RAF University of London Air Squadron. After graduation in 2002, I joined a global company that supplied metallics to the aerospace industry. In 2009 I became a full-time Ph.D. candidate and expect to graduate in 2012. It is a personal imperative that the product of my Ph.D. is of benefit to the accident investigation community as well as to the academic community. The Kapustin Scholarship has provided me with a fantastic opportunity to assist in my aspirations to work within the investigation community, whether it is through the training opportunities it provides or through the exposure to the accident investigation community. This would not be possible if it were not for the generosity of those who donated to the ISASI, Rudolf Kapustin Memorial Scholarship program, ISASI, and the training institutes who offered free attendance to courses. To these I am exceptionally grateful." ◆

The Scholarship essays of the awardees follow.

The Untraceable Aircraft Accidents

By Maggie Wong

Among the many problems such as stress, fatigue, time restraints, and legal issues that air safety investigators confront, the biggest challenge is determining the causes of an accident when little evidence is available. When an aircraft accident occurs, air safety investigators are interested in knowing what happened, why it happened, and how they can prevent it from happening again. However, the challenge becomes greater when the black boxes (cockpit voice recorder and flight data recorder) and other critical information cannot be recovered. With the lack of information, investigators have to gather and link all the tiny bits of evidence to determine the causes. Sometimes, witness statements, air traffic control data, maintenance records, and small amounts of debris may be the only evidence that is available. The automated dependent surveillance-broadcast (ADS-B) is a new technology that can enhance aircraft accident investigations by providing additional, precise flight data.

Aircraft accidents do not always happen in a convenient place where all vital evidence can be easily recovered. For instance, Air France Flight 447 was an over-the-sea aircraft accident that has a complicated investigation. The Airbus crashed into the Atlantic Ocean on June 1, 2009. It was the first accident in many years that left almost no trace for the investigators to examine (Michaels and Pasztor, 2010). The flight departed from Brazil and intended to land in Paris. Before the crewmembers lost communication with air traffic control, they sent out numerous aircraft communications addressing and reporting system (ACARS) messages before crashing into the Atlantic Ocean. All 228 people on board were assumed deceased after long searches. Currently, 10 months after the crash, search ships have been launched again for their third attempt to locate the black boxes.

Similar to Air France Flight 447, Yemenia Airways Flight 626 also had difficulty in recovering the black boxes. The flight originally departed from Paris and intended to land in Sana'a, Yemen's capital, on June 30, 2009. When it took off again to Comoros, the aircraft crashed into the Indian Ocean with only one survivor. Search teams struggled to locate the black boxes but eventually recovered them. With over-the-sea accidents like Air France Flight 447 and Yemenia Flight 626, the chances of recovering the black boxes and other vital evidence become bleak. Furthermore, the Atlantic Ocean and Indian Ocean are more than 13,000 feet deep. The ocean currents may even move the debris and black boxes to remote areas. Thus, information or evidence that is available to investigators becomes scarce. It elevates the difficulty level in conducting an investigation.

An aircraft accident investigation is like composing a gigantic puzzle. Without a sample image of it, it is hard to put it back together. An investigation becomes challenging if the sample image, or the black boxes, is not accessible. Since the mid-1970s, missing or damaged black boxes have blocked investigations in a small number of major airline crashes (Michaels and Pasztor, 2010). Just like Air France Flight 447, investigators are still unable to determine the causes of the accident because of the inability to locate the black boxes and other significant information. Although an accident may have eyewitnesses available to investigators, psychologists estimate that humans are only able to recover about 30% of what they see (Wood and Sweginnis, 2006). Sometimes witnesses may have poor memory and distance estimations. Different age groups may provide different statements based on their experience and level of education. They can also be biased about what they see according to their backgrounds. Furthermore, their aeronautical vocabulary may be limited to describe certain aircraft parts, and they may give inaccurate descriptions. Therefore, investigators cannot solely rely on witness statements. Similarly, if only air traffic control radar data, maintenance records, and some insignificant debris are obtainable, the investigators will probably have no other ways to seek information.

An aircraft accident investigation is like composing a gigantic puzzle. Without a sample image of it, it is hard to put it back together. An investigation becomes challenging if the sample image, or the black boxes, is not accessible. Since the mid-1970s, missing or damaged black boxes have blocked investigations in a small number of major airline crashes.

If an accident aircraft is equipped with the ADS-B, investigators will have an extra source for accurate flight information. ADS-B's main purpose is to provide real-time flight information to pilots and air traffic controllers in order to improve aviation safety. However, ADS-B can supply the investigators with additional information of the flight when black box or full wreckage recovery is impractical.

According to ADS-B Technologies, LLC, although the information that ADS-B contains may not be as thorough as the black boxes, it is able to provide precise and real-time information such as speed, heading, altitude, flight number, weather, and terrain information without degradation due to atmospheric conditions and range. It is a satellite-based global positioning system that broadcasts the aircraft position and other data to other aircraft and ground stations that are equipped with ADS-B. Along with the ADS-B software, flight data can be collected on the ground and is always accessible. Along with the air traffic control audio recording, the ADS-B flight data can be a valuable investigative tool that can give a much better picture of the events leading to an accident and reduce hindsight bias (Zwegers, 2009). With ADS-B, investigators will at least be able to have a basic understanding of what an ADS-B-equipped aircraft was doing before a crash when other data are limited.

An aircraft accident investigation with limited information is often a challenge to investigators. Fortunately, ADS-B is a new technology that can aid aircraft accident investigations by providing additional flight information, despite the wreckage location. As long as an aircraft is equipped with ADS-B, investigators will be able to know its flight information such as speed, altitude, and direction at a minimum when other critical evidence cannot be retrieved. ADS-B is not only a great investigative tool, but it can also improve overall aviation safety by providing real-time and accurate information to pilots and air traffic controllers.

In 2007, the FAA issued a notice of proposed rulemaking (NPRM) that planned to require all aircraft operating in the United States to install ADS-B by 2020. Besides the FAA, according to *Air Safety Week*, the Air Transport Association (ATA) and its member airlines are also strong advocates of this new technology. The European Union and other European aviation organizations also support installing ADS-B, especially after the tragedy of Air France Flight 447. If Air France Flight 447 was equipped with ADS-B, investigators would have a fundamental understanding of the accident, be able to give answers to the families and friends of the victims, and possibly prevent the accident from happening again. ◆

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Shaping the Future of Unmanned Operations: The Challenge for Aircraft Safety Investigators

By Logan Jones

As we reflect back on the last 100 years of manned flight, we recognize the crucial role that aircraft safety investigators (ASIs) have played in ensuring aviation safety. Their investigations and resulting safety recommendations from accidents and incidents have led to air travel continually reducing its accident rate to the record low levels of today. As we enter the second century of flight, a new type of aircraft operation is on the verge of entering into commercial use: unmanned aerial systems (UASs). UASs pull the pilots out of the cockpit and place them in front of a control station, where they can either monitor autonomous operations of the vehicle or take control and pilot the vehicle themselves. UAS use can be broken down into three sectors: military, civil, and commercial. Military use of UASs is wide spread, but they are generally operated outside of the national airspace (NAS). Civil use is limited and is granted on a case-by-case base, while commercial use is currently prohibited due to the lack of regulations. Nevertheless, the potential benefits of UASs in the commercial and civil sectors, for operations such as crop monitoring, search and rescue, weather monitoring, and others, have authorities currently deliberating regulations.

Unmanned operations represent a fundamental change to the manner in which vehicles travel through our airspace. This fundamental change means that new regulations may be necessary to encompass UASs. As with any new type of technology, incidents and accidents are inevitable; aircraft safety investigators will play a critical role, particularly in the early years of UAS operations, in shaping the regulatory landscape and making recommendations to ensure safety in the skies.

Several challenges exist for ASIs in analyzing UASs due to their considerable range of size, mass, and velocity. Due to the fact that there are currently no specific regulations classifying different unmanned platforms, each investigation is treated on a case-by-case basis. The results from these preliminary investigations will aid in categorizing future UAS operations based on the notion of acceptable risk.

UASs can take a vast range of size, shape, and form: from micro-drones weighing less than 1 lb to large aircraft weighing more than 40,000 lbs. Regulations must be put in place to ensure that during UAS operations, safety is maintained for pilots in the air and the public on the ground. At the same time, new regulations should take care not to unnecessarily burden this new industry. The operational risk posed by a 10,000-lb Predator B UAS and the 430 g Wasp UAS are clearly different. However, the risk is defined not only by size, but also by area of operation. The same 430 g Wasp UAS operating in an urban setting poses a different risk than a Predator B operating over the Pacific Ocean. It is apparent that defining acceptable risk will not be straightforward. Therefore, the categorization of UASs will depend on several factors such as size, velocity, area of use, pilot experience, platform reliability, system redundancy, and more. Regulations clearly cannot be "one size fits all." A balance must be found to satisfy both safety concerns and industry.

The investigations into UAS incidents and accidents will play a large role in determining where to draw the line between different types of UAS operations. By analyzing incidents and most importantly by asking the "what if" questions, investigators will provide invaluable knowledge regarding the acceptable risk posed by the great variety of UASs. One of the most important factors in determining acceptable risk is reliability.

The hurdle to widespread unmanned aerial systems (UAS) use is the regulations governing safe operation in the national airspace. The reports and safety recommendations from ASIs will shape the categorization of UASs and ensure that the benefits of civil and commercial applications of UASs can be achieved while maintaining safety in our skies.

In September 2008 at the ICAO General Assembly, a proposal was made to include the routine collection of UAS accident and incident data (La Franchi, 2007). The analysis of this data is necessary to determine the reliability that UAS platforms can provide. With a database of UAS incidents and accidents, ASIs and regulators can determine operational weak points and establish where system redundancy is needed.

The importance of this issue was brought forth during the first-ever civil UAS accident investigated by the NSTB. A brief background into the accident: On April 25, 2006, a 10,000-lb Predator B UAS, operated by the Department of Homeland Security, had its fuel flow valve accidentally shut off during a changeover in control units. This cascaded into a loss of data-link with the pilot and subsequent crash into terrain. The ensuing NTSB investigation yielded deficiencies in all aspects of the UAS operation: pilot experience, incident reporting, ATC communication, A/C airworthiness, emergency procedures, and the lack of a safety plan to identify hazards (NTSB 2006). In total, the NTSB issued 22 safety recommendations. Regarding the accident, NTSB chairman Mark V. Rosenker said, "The fact that we approved 22 safety recommendations based on our investigation of a single accident is an indication of the scope of the safety issues these unmanned aircraft are bringing into the national airspace system." (SecurityInnovator, 2007)

One of the key recommendations from this accident investigation was incident reporting. Quoting from the NTSB safety recommendations: *"Require that all unmanned aircraft operators report to the FAA all incidents and malfunctions that affect safety; require that operators are analyzing these data in an effort to improve safety; and evaluate these data to determine whether programs and procedures remain effective in mitigating safety risks." (NTSB, 2007)*

In fact, during the accident investigation, it was found that the initial failure, the lockup in the ground control unit, occurred nine times in the previous 3 months and yet the root cause of these lockups was never discovered. Oversights such as this are not tolerated in commercial manned flight operations, and clearly should not be for unmanned operations either. The NSTB concluded that "now is the time…to build critical safety knowledge on how to operate UASs." (NTSB, 2007)

The hurdle to widespread UAS use is the regulations governing safe operation in the national airspace. These regulations will be based on providing an acceptable level of risk in the air and on the ground. An effective process for the reporting and analysis of incidents and malfunctions will provide essential knowledge for UAS design and will mitigate the risk of a catastrophic accident. These early investigations by ASIs will provide the framework for future UAS regulations and design. The challenge to aircraft safety investigators will be to take into account all of the factors involved in the operation of UASs and determine the risk posed. Reliability, size and weight, area of use, pilot experience, and system redundancy all will contribute to the risk. The reports and safety recommendations from ASIs will shape the categorization of UASs and ensure that the benefits of civil and commercial applications of UASs can be achieved while maintaining safety in our skies. ◆

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The Challenges for Air Safety Investigators: From Kicking Tin to Kicking Composites

By Leigh Dunn

Composite materials are not new to either the aerospace industry or to accident investigators. It was as early as 1957 when the FS-24 Phoenix, a sailplane constructed almost entirely from a glass fiber reinforced polyester resin and balsa sandwich, first flew. It is only in recent years, however, that composite materials have taken prominence in new commercial aircraft designs. The Boeing 787, which first flew in December 2009, contains approximately 50% composite material by structural weight with the aluminum content being 20%. In contrast, the Boeing 777, which first flew in June 1994, contains 12% composite materials and 50% aluminum.

A significant challenge for air safety investigators is keeping up with developments in aircraft technologies. One current and significant development is presented by composite materials. As Rakow & Pettinger (2006) suggested at ISASI's 37th annual international seminar, "Aircraft structures of the current decade are progressing through a major transition from metallic structures to composite structures, similar to the transition from wood to metal in the 1920s."

This apparent shift in airframe technology presents various challenges for air safety investigators. In the event of a major accident involving a composite airliner such as the Boeing 787 or Airbus A350, the initial reaction of the news media is likely to question the safety of composite materials. This pressure will be intensified by the general public whose primary source of information is through the news media. The world may well be suddenly looking to investigators to answer the question, "Are composite aircraft safe?"

Composite materials, unlike aluminum, are relatively young in the development cycle and are undergoing significant advancement and variations in designs. For example, the fuselage of the A380 contains GLARE, the Boeing 787 fuselage is filament wound carbon fiber, and the A350 fuselage is constructed of carbon fiber panels. These differences in design are likely to complicate the investigation of composite material accidents.

What failure mechanisms are investigators likely to face? In 2002 Qinetiq, which provides forensic analysis of structural failures to the UK AAIB, observed that the top three metallic failure mechanisms were fatigue (55%), corrosion (16%), and overload (14%) (Findlay & Harrison, 2002). This result is perhaps not surprising as typically the fatigue limit of light alloys can be as little as 10% of the ultimate static strength. This experience has provided an understanding to the accident investigation community as to how metallic aircraft prematurely fail. Composites, on the other hand, are relatively fatigue resistant. Significant fatigue crack growth may not develop until 60% of static failure stress so will we see fewer traditional fatigue failures?

Delamination is a failure mechanism that is considered a significant issue for laminate composite materials but one that does not affect traditional aluminum materials. Delamination involves the subsurface separation of plies of a laminate and may be initiated by relatively low energy impacts. The full extent of such damage may remain barely visible under visual examination. Thus early detection is reliant on nondestructive evaluation (NDE). Ransom et al (2008), however, has recently questioned the effectiveness of NDE inspections claiming that "nondestructive evaluation (NDE) techniques of complex structures are generally inadequate to detect damage during typical in-service inspections."

The understanding of metallic failure modes and how to make a preliminary visual identification has benefited from decades of failures and subsequent investigations. In the case of metal fatigue, Wanhill (2002) discusses advances in the knowledge of fatigue linked to notable aircraft accidents such as the Comet disasters of 1954, which gave a general awareness of finite aircraft fatigue life, the F-111 wing failure in 1969, which highlighted that aircraft should be damage tolerant; the Dan Air 707 accident in 1977, which presented the fatigue of geriatric aircraft; and the Aloha Airlines 737 accident in 1988, which highlighted multiple site fatigue damage.

Unfortunately, this accrued knowledge and understanding of metallic failures cannot necessarily be transferred to the understanding of composite material failures due to key differences between metallics and composite materials. In the case of metallics, a suspect fatigue-initiated failure may be visibly identified by beach marks and the presence of two distinctly different fracture zones. These visual clues can also provide the investigator with an indication as to the initiation site. In the case of composites, visual examination of most failure modes can be complicated through a substantial increase in the number of fracture surfaces, a general difficulty in visual identification, a high susceptibility to post-fracture damage, and the lack of any significant permanent deformation. In the case of the latter, the permanent deformation of metallic structures can provide valuable clues as to what was occurring to the aircraft prior to or at the time of impact.

The understanding of metallic failure modes and how to make a preliminary visual identification has benefited from decades of failures and subsequent investigations.… Unfortunately, this accrued knowledge and understanding of metallic failures cannot necessarily be transferred to the understanding of composite material failures due to key differences between metallics and composite materials.

For example, Frank Taylor (1998), in his paper discussing the wreckage analysis of a DC-9 operated by Itavia that crashed off Ustica, discusses how the permanent deformation of the aircraft structure can be used to determine the break-up sequence and to locate the most probable position of an explosive device. An absence of this "recording" of evidence may have major implications on accidents where evidence from alternative sources is limited.

The above has briefly highlighted the challenges of composite failure analysis, the diversity of materials, and the projected growth in composite material technology. In addition, other challenges include accident site hazards and crashworthiness investigations. So how does the investigation community meet these challenges? Steps could include the sharing of accident experiences, the creation of literature, such as those produced by Exponent and the ATSB, conducting academic research, or by learning from the experience of other sectors. The most important step, which is relevant to all of the above, is through the sharing of information within the investigation community. This is where ISASI, as a society established to promote air safety by the exchange of ideas, experiences, and information, offers the ideal platform to ensure the challenges presented are met by the community and not left to the individual investigator. ◆

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Helicopter EMS Operations—

The authors explain the special challenges in air medicine through a comprehensive and statistical

By Christine Negroni (FO5208) and Dr. Patrick Veillette

(This article is adapted with permission from the authors' paper entitled At What Cost? A Comprehensive and Statistical Analysis of EMS Helicopter Accidents in the United States from 1985 to 2007 *presented at the ISASI 2009 seminar held in Orlando, Fla., Sept. 14-18, 2009, which carried the theme "Accident Prevention Beyond Investigation." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

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

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

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

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

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

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

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

Threats to safety will emerge in every flight. Removing the known threats is an important first step. The NTSB has issued multiple sets of safety recommendations going back to 1988. The FAA has chosen to suggest rather than mandate many of these recommendations. The analysis of the CMAS database and ASRS reports also leads us to make several safety recommendations.

History

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

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

From one in 1972, hospital helicopter

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Photo Not Available

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—At What Cost?

analysis of EMS helicopter accidents in the United States from 1985 to 2007.

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

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

What is medical transport?

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

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

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

As a result, in 2009, less than half—40%—of HEMS operators had terrain awareness and warning systems (TAWS); slightly more than half—57%—used twin-engine aircraft and were therefore capable of autopilot or IFR; 30 % used night vision goggles; and less than 1% of HEMS operators fly two-pilot crews.

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

Since its first hearing on EMS safety in 1988, the NTSB has held two more hearings urging the FAA to mandate certain equipment and operational practices. In 2009 the NTSB recommended requiring all EMS operators to

- operate under Federal Aviation Regulations Part 135 on all flights with medical personnel on board (A-06-12),
- use risk evaluation programs and train in the evaluation of flight risks (A-06-13), requiring EMS operators to use formalized dispatch and flight-following procedures including up-to-date weather information flight risk assessment decisions (A-06-14),
- install terrain awareness and warning systems on aircraft and train flight crews on the use of this equipment (A-06-15).

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

Threat and error management

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

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

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

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

PHOTO: NTSB

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

"*Problem areas: The quick EMS helicopter responses, the numerous interruptions of the EMS pilot during start-up, and the pilot allowing this to happen. Plus, the added pressure of a dying person causing the pilot to make emotional decisions instead of safe ones.*" (Italic added for emphasis) (NASA ASRS Accession Number 118240)

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

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

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

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

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

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

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

Of the 210 accidents in the CMAS database over the past 20 years, 69—or 1 in 3—involved the aircraft hitting something. Confined-area operations were present in 29% of the ASRS reports. HEMS pilots frequently deal with limited maneuvering room, proximity of obstacles, lack of information about obstacles, inadequate lighting to detect obstacles, adverse wind conditions during departure from a confined area, and a lack of guidance from the ground to avoid obstacles. Approximately 14% of the ASRS reports indicated this threat had not been adequately managed.

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

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

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

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

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

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

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

The lack of on-site weather reports also impacts the preflight go/no-go decision. Weather reports are often a significant distance from the destination, making it difficult for EMS pilots to make an educated decision. Examining NTSB accident reports, the nearest weather reporting stations in 10 accidents were 15 to 25 miles away, and in 8 accidents the weather reporting was even more remote. One was 47 miles away.

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

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

Since weather and reduced visibility (including night flight) creates layers of risk, management is required on several fronts. Between 1987 and 2008, there have been 305 EMS helicopter accidents or significant safety incidents in the United States, according to the CMAS database, and nearly half of them occurred either at night or in weather that obstructed the pilot's vision.

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

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

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

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

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

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

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

PHOTO: NTSB

SMOOTHING CDR RADAR DATA

The authors perform a comparison study of GPS data and CDR radar data using a fully instrumented flight test to try to eliminate some of the discrepancies that result from differing interpretations of radar data.

By Ryan M. Graue, W. Jeffrey Edwards, Jean H. Slane, Dr. Robert C. Winn, and Krista B. Kumley

(This article is adapted with permission from the authors' paper entitled A Comparison Study of GPS Data and CDR Radar Data Using a Fully Instrumented Flight Test *presented at the ISASI 2009 seminar held in Orlando, Fla., Sept. 14-18, 2009, which carried the theme "Accident Prevention Beyond Investigation." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

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

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

Radar data analysis involves two major aspects in the context of aircraft accident investigation: flight path reconstruction and flight parameter reconstruction. Flight path reconstruction is important because it tells the investigator where the aircraft was located at specific times throughout the flight. Flight parameter reconstruction is also critical because it gives the investigator an understanding of how the aircraft performed in order to generate the radar recorded accident flight. As both of these aspects are key components of aircraft accident investigation, the flight test data analysis will include comparisons of the flight paths and the flight parameters.

Experimental setup

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

To model various segments of accident flight scenarios, the following maneuvers were flown: straight and level, climb, descent, S-turns, steep turns, chandelles, instrument approach,

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and autopilot turn. The recorded radar data from each maneuver were processed using four levels of smoothing and two calculation methods. The flight parameters were calculated for each combination of smoothing level and calculation method. The flight parameters compared in this study were ground speed, true airspeed, bank angle, load factor, magnetic heading, and turn rate.

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

Radar facility and description of radar data—Radar data were gathered from the St. Louis/Lambert (KSTL) Terminal Radar Approach Control (TRACON) ASR-9 antenna. Information obtained from the radar data file included the times of the radar returns, range, and azimuth angle relative to the antenna and Mode C (pressure) altitude.

Flight path—The flight lasted approximately 2 hours and was flown in the area west of St. Louis in east central Missouri. More than 1,300 radar returns were obtained from the flight.

Analysis

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

The flight test occurred in an area nearly equidistant from the Lincoln, Ill., and Springfield, Mo., stations approximately 2 hours before the 0 UTC weather recording. For the flight parameter analysis, the average winds and temperatures between these two stations were used.

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

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

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

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

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

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

The results shown in Table 1 lead to the following conclusions:

• For straight flight (straight and level, climb, descent, and instrument approach), high levels of smoothing generally resulted in the best agreement with the onboard recorded position data.

• For maneuvering flight (S-turns, steep turns, chandelles, and autopilot turns), little or no smoothing generally gave the closest agreement.

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

The process of calculating the flight parameters is based on the seminal work done for NASA by R.E. Bach and R.C. Wingrove. In their 1980 work, "Equations for Determining Aircraft Motions from Accident Data," the path between smoothed points is described by a straight line—a rectilinear approach. Recognizing

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

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

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

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

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

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

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

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

Table 2. Flight Parameter Mean Absolute Error Results

that an airplane cannot abruptly change direction at a point, a curvilinear approach was developed by J.H. Slane and R.C. Winn in "A Curvilinear Approach to Flight Path Reconstruction from Recorded Radar Data." In the curvilinear approach, a circular flight path is defined by three consecutive smoothed points. In both methods, the path between the points does not have to be in the horizontal plane.

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

These results lead to several observations. As a general rule, nearly straight flight is best analyzed using high levels of smoothing, while maneuvering flight is best analyzed using low levels of smoothing. This is consistent with the earlier finding regarding the smoothing levels that resulted in the best flight paths. Here are some additional findings:

- In almost every case, the calculation of true airspeed resulted in significantly larger error than the calculation of ground speed. To calculate true airspeed from ground speed, the winds at altitude were needed. Errors in the calculation of true airspeed were likely higher because of errors in the wind profile at altitude.
- For straight and level, climb, and descent, the best results were obtained with 9 and 13 point smoothing for both rectilinear and curvilinear analyses. For the instrument approach, the calculation of ground speed using rectilinear analysis with 13 point smoothing was slightly more in error.
- For S-turns, steep turns, chandelles,

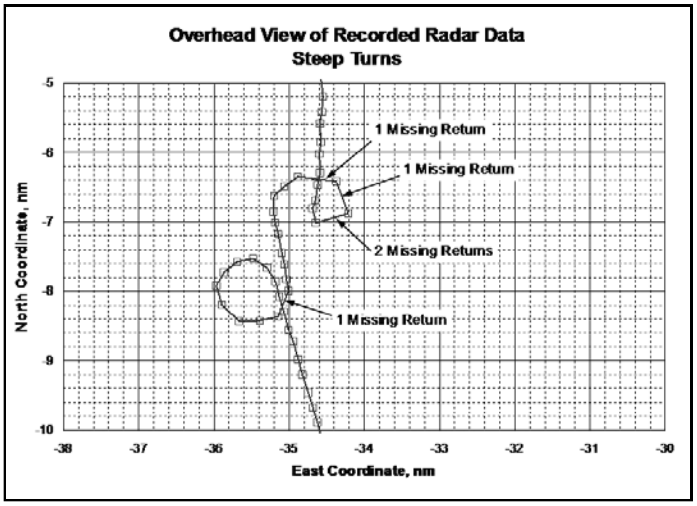

Figure 1. Ground track during steep turns.

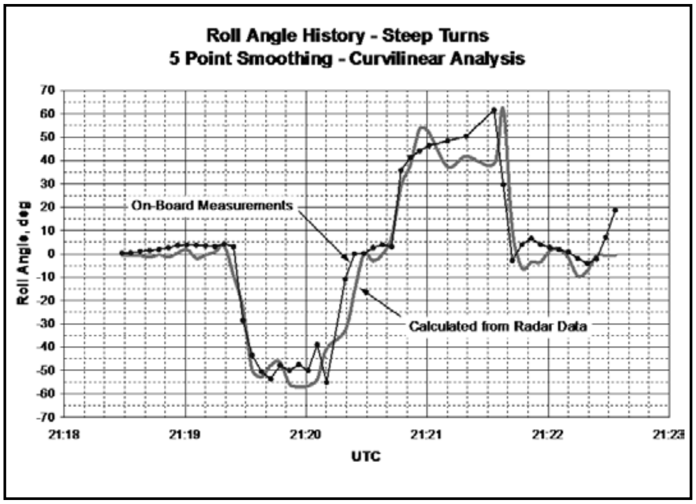

Figure 2. Calculated and measured bank angle during steep turns.

and autopilot turns, low levels of smoothing are preferred; however, in most cases, 5 point smoothing yielded better results than no smoothing. Using high levels of smoothing generally results in the smoothed points being placed toward the inside of each turn. This causes the calculated distance travelled to be less than actual; therefore, the calculated ground speed is lower than actual.

- For S-turns, steep turns, chandelles, and autopilot turns, the errors in heading are quite large; however, this is expected when considering that the heading changed very rapidly during these maneuvers. In nearly straight flight in which heading could be an important issue, the calculated headings are quite accurate.
- In general, for S-turns, steep turns, chandelles, and autopilot turns, curvilinear analysis is superior to rectilinear. This is due to the fact that the curvilinear analysis considers the airplane flying in a curved path between points, creating a much more realistic reconstruction than the airplane flying a straight path and turning abruptly at each point.

To determine bank angle for steep turns, the best approach was determined to be 5 point smoothing with either the rectilinear or curvilinear approach; but even so, the calculated bank angle was still rather high. The explanation for this finding can be found by looking at the radar returns that were missed by the radar facility. In Figure 1, the radar data and the ground track of the airplane are shown. Notice that in the second (more northerly) of the two steep turns, several radar returns are missing. These missing returns are due to the airplane's transponder antenna being shielded from the radar station. With several key radar returns missing, the distance between points is far less than the distance actually flown by the test airplane. For an unknown reason, the more southerly of the two steep turns was only missing one return. In Figure 2, the calculated bank angle history for this maneuver is shown. Notice that the first turn is reconstructed very accurately compared to the second steep turn; however, the results presented in Table 2 include the errors from both turns. This example shows the importance of critically studying the radar data before accepting the results.

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

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

Conclusions

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

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

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

ACCIDENT PREVENTION:

Pushing the Limits

Within the framework of existing European Union (EU) treaties and institutions, the adoption of Regulation (EC) No. 1592/2002 of the European Parliament and of the Council of July 15, 2002, established a European Aviation Safety Agency (EASA) tasked to establish and maintain a high uniform level of civil aviation safety in Europe.

By Bernard Bourdon, Accident Investigation Manager, European Aviation Safety Agency, the European Union

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

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

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

The new regulatory framework: the total system approach

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

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

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

The gathering of executive functions is made in 3 steps:

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

Therefore, the EU aviation system is now based on shared responsibilities among members States, the European Commission, EASA, and the industry. Member States are essential pillars for implementing rules in their territory while EASA promotes

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community views regarding civil aviation safety standards and rules and, therefore, has taken executive powers in

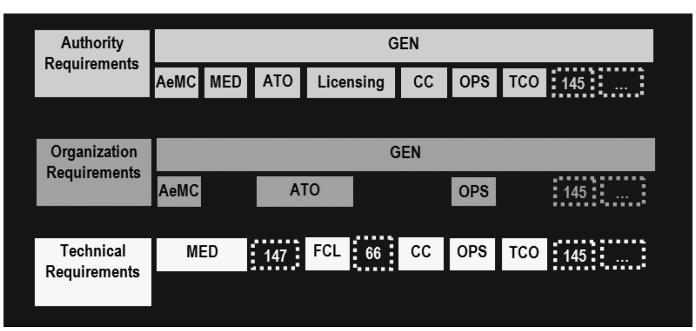
- production of all EU legislation and implementation materials related to the regulation of civil aviation safety and environmental compatibility, including products certification, licensing, and operations;
- cooperation in setting international standards;
- type certification and continued airworthiness of products, parts, and appliances;
- environmental approval of products;
- approvals of organizations;
- standardization of States and the oversight of compliance with common rules; and
- oversight of non-EU operators flying to Europe.

The new regulatory framework: a proactive approach to safety risks

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

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

The new regulatory scheme defines the authority and organization requirements applicable to States. The regulatory scheme aims at improving the harmonization of requirements in terms

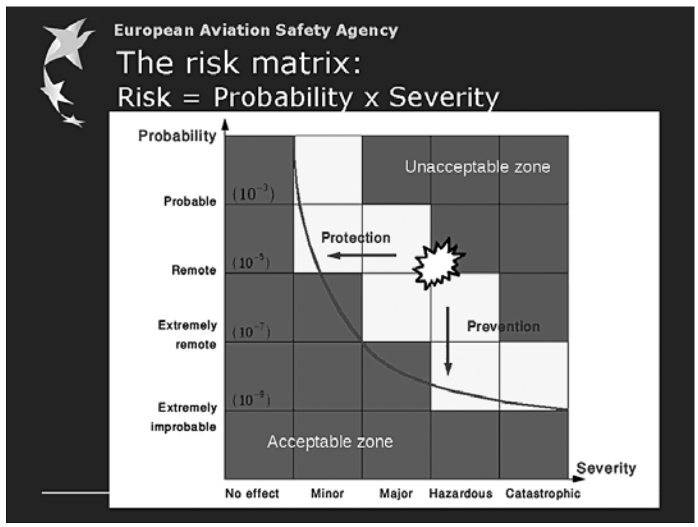


AeMC: Aeromedical Center
MED: Medical
ATO: Air Transport Operator
147: Training Organization
FCL: Flight Crew Licensing
66: Maintenance Certifying staff
CC: Cabin Crew
OPS: Operations
TCO: Third Country Operators
145: Maintenance Organization

of reporting, personnel, and record keeping, while taking into account the specificity of each field. As a consequence, an air operator already approved for air transport operation would extend its activity to maintenance using its already approved general organization requirements and focusing only on the specific technical requirements for the new business. It will also avoid duplicating tasks during the oversight process (see chart below left).

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

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



Therefore, it's paramount that accident investigation authorities report and issue safety recommendations that close the safety loop to the EU safety system. This helps the following aspects of the risk assessment:

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

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

ADREP, ICAO's accident indent data reporting system, is based on a core common taxonomy for recording, exchanging, and classifying occurrences. Therefore, cross-checking similar factors using a central database is made possible with tools like Eccairs, which promotes the proactive approach to safety deficiencies. ◆

NTSB Chair Hersman Addresses MARC Spring Meeting

National Transportation Safety Board Chairman Deborah A.P. Hersman was the guest speaker at the ISASI Mid-Atlantic Council (MARC) annual spring dinner meeting held in Herndon, Va., April 29. The event was held in conjunction with the spring ISASI International Council meeting. ISASI President Frank Del Gandio also addressed the group.

During a refreshment hour, the 61 attendees caught up on "hellos" to those friends who hadn't been seen in a while. MARC President Ron Schleede called the meeting to order and outlined the evening's program, thanked corporate members for the donation of the many door prizes that lined the gift table, and announced that among the prizes were three sets of roundtrip airline tickets for travel to any destination within the U.S. Tickets were donated by Southwest Airlines, AirTran Airways, and jetBlue Airways. Other door prize contributors included the Air Line Pilots Association; Airbus; RTI Group, LLC; Continental Airlines; Julie Fischer Photography; the University of Southern California; and Crowne Plaza Hotel.

In his opening talk, Ron described the funding methods used for the ISASI Kapustin Scholarship fund, noting that contributions made in the U.S. to the fund were tax-deductible and that all funding comes from contributions. He emphasized that no member dues monies were used to fund the Scholarship.

Because at the time of his passing Rudy Kapustin was the president of MARC, a special fundraising tradition exists at this meeting. This year the MARC Chapter kicked it off by contributing $500 and challenging higher contributions. The Pacific Northwest Regional Chapter, Kevin Darcy, president, met the $500; Canadian Society of Air Safety Investigators, Barbara Dunn, president, raised it to $502, and the Dallas-Ft. Worth Chapter, Tim Logan, president, capped the challenge with a contributing bid of $503. Other contributors were Chris Baum, Denise Daniels, Frank Del Gandio, Lucky and Virlene Finch, David J. Haase, Robert (Bob) Hendrickson, Tom and Ginger McCarthy, Richard Newman, Alissa Rojas, John Purvis and Nancy Wright, Kelly Skyles, Ron Schleede, and Richard and Ruth Stone for a grand contributed total of $3,775.

Just prior to calling Dick Stone, the co-chair of the Scholarship program, Ron reminded all that donations could be made at anytime. He noted that full information is on the ISASI website, www.isasi.org. Stone spoke of the 2010 selection process. He noted that more than a half-dozen entries had been received, of which three were selected to receive the scholarship: Leigh Dunn, a Ph.D. candidate with a special study area of composite materials; Logan Jones, a Ph.D. candidate with a study area of modeling aircraft takeoff and landing on contaminated runways; and Maggie Wong, a third-year student with a study area of crash survivability analysis and design and safety program management. Stone said, with a measure of pride in his voice, "This is the caliber of students that your money is helping to bring to ISASI seminars."

Barbara Dunn, chair of the national seminar program, also addressed the group. She said "We are going to have an exciting 3 years." First, she gave the most current update on the upcoming ISASI seminar in Sapporo, Japan, September 6-9, saying that more information is available via a link through the ISASI website, www.isasi.org. She described a new registration method utilizing a private "online" company and added that the seminar site is "very user-friendly." She added, in a cautionary tone, that hotel registration must be made through the link on the ISASI website. In addition, she said planning was in full swing for the seminar to be held in Salt Lake City, Utah, Sept. 12-15, 2011. She also announced that ISASI 2012 is scheduled to be held in New Zealand and is to be hosted by the New Zealand Society.

Speaker Toby Carroll outlined the program "Learning from Investigations" to be presented by the U.S. Society in June 2010. The program, he said, will include three tracks during the 2 full days of training: general aviation, commercial, and helicopter. To some USSASI investigators' recollections, this seminar is a "first" for the Society.

ISASI President Del Gandio welcomed all and followed Stone's lead about the worthiness of the Scholarship program. He said that the "poise and demeanor shown by one of last year's [2009] selectees would make one think the 22-year-old was a veteran of the business. He is definitely a young man who is going to be filling a high-level position sometime in the future in this business." Moving his attention to ISASI's highly successful Reachout program, which was started 8 years ago, he noted that in that time it has reached almost 2,000 persons in 21 countries. "I can't say that we prevented a lot of accidents," he said, "but I truly believe we have. We just can't count them."

Following a re-presentation of the Jerome F. Lederer Award plaque to Richard Stone, because the original plaque was "misplaced" at ISASI 2009, he introduced NTSB Chairman Deborah A.P. Hersman. She addressed ISASI 2009 as the keynote speaker, just 7 weeks after being confirmed as the 12th NTSB chairman. Then, her talk addressed the seminar's theme "Accident Prevention Beyond Investigation" by asking the question "What is Next?" to a room full of people who spend their time solving puzzles, putting things back together to figure out what failed and how a design can be improved.

On this occasion, Chairman Hersman in opening her talk said, "I am so


PHOTOS: E. MARTINEZ

FAR LEFT: Chairman Hersman addresses the MARC audience.
LEFT: Tom McCarthy helps a door prize winner make a selection.

grateful for the opportunity to visit with the men and women of ISASI who really share a passion for aviation safety and making aviation as safe as it can be."

She then went on to discuss data-driven systems to improve aviation safety. She told the audience that the use of data to manage and improve safety in the aviation industry has had a positive effect on the world's improving aviation safety record. But she cautioned against overreliance on these systems to the neglect of forensic investigation. She noted, "We have reached an era in which aviation accidents are extremely rare...." One reason is the use of data—particularly, but not exclusively, safety management systems (SMS)—in accident prevention and investigation.

She added, "The Board has been advocating the use of SMS for a decade, having issued 17 recommendations in favor of implementing SMS in the aviation industry. When implemented correctly, SMS holds real promise in a variety of scenarios." She noted several instances in which SMS helped eliminate potential unsafe conditions, notably a corporate flight operation that used flight data to determine that high bank angles occurred on repositioning flights, and a review of commercial aircraft approach data that indicated a high rate of TCAS [Traffic Alert and Collision Avoidance System] warnings at a particular airport. In these instances, she said, "data management adeptly identified a clearly measurable set of information and allowed for a relatively simple and effective solution."

However, Hersman noted that SMS works well for companies that are already "getting it right," but may provide little more than false confidence for companies with less-than-robust safety cultures. Also, there are accidents caused by a combination of factors that SMS cannot possibly detect. As an example, Hersman mentioned the British Airways Boeing 777 crash at Heathrow Airport 2 years ago involving a dual-engine failure on approach. It was not data analysis that solved the mystery, but detailed forensic analysis—the circumstances were so unusual that a data analysis system would not pick them up.

Hersman said she hoped that with all the focus SMS will place on data collection and analysis, "let's not lose focus on outcomes. The success of SMS won't be measured by how much data we collect, but by how many lives we save.

"I will enthusiastically support any approach that will make our nation safer," she said. "But I think we need a measured approach—one that acknowledges the potential benefits and limitations of SMS and, further, doesn't discount tried-and-true methods for identifying vulnerabilities, such as accident investigations." ◆

2010 Int'l Council Election Voting Is Under Way

The 2010 ISASI International Council Election voting period will run June 15 to Aug. 15, 2010. This year's election will be conducted electronically via the Internet using VoteNet. The goals for implementing the electronic ballot are to make it easier and faster for members to vote and to significantly reduce postage, labor, and materials costs. The process is easy, and there are readily understandable prompts to take you to the ballot so those eligible members may cast their vote.

All incumbents are standing for reelection. In addition, Paul Mayes has been nominated for the office of ISASI vice-president. He will run against the present incumbent, Ron Schleede. Other present incumbents are President, Frank Del Gandio; Secretary, Chris Baum; Treasurer, Tom McCarthy. The offices of international councillor and the U.S. councillor are also open for election. Present incumbents, Caj Frostell and Toby Carroll, are both standing for reelection. No other nominations for those offices have been received.

Members can log on to the ISASI website, www.isasi.org, and a link to VoteNet will appear on the home page. Click on the link and follow the easy-to-use instructions. There are three ballots available: one for U.S. members, one for members of national societies, and one for international members. When you input your member number the correct ballot will automatically show itself. There is also a box you can check for a write-in candidate. Voting is strictly confidential, and only the results will be available to the Ballot Certification Committee.

If any eligible member does not or cannot find access to the Internet to vote, he or she may contact Ann Schull or Tom McCarthy at the international office and a paper ballot will be made available. Contact may be made by calling (703) 430-9668, faxing (703) 430-4970, and e-mailing isasi@erols.com.

The following members are not eligible to vote: Affiliate Members, Corporate Members (status only), Honorary Members, and Student Members. **The following ISASI members are eligible to vote:** Fellow Members, Full Members, Associate Members, Life Fellow Members, Life Full Members, Life Associate Members, Life Charter Members, Charter Members. U.S. members will vote for the president, vice-president, secretary, treasurer, and the U.S. councillor, and international members will vote for the president, vice-president, secretary, treasurer, and the international councillor. Society members will vote for the following: president, vice-president, secretary, and treasurer. ◆

Schleede, Mayes Vie For Int'l VP Office

Ron Schleede, ISASI vice-president, and Paul Mayes, the current secretary/treasurer of the Australian Society, are both candidates for the office of ISASI vice-president during the ongoing Executive officer position elections. Those elected take office upon the completion of the annual seminar on September 10.

Schleede has served as ISASI vice-president since 2002 and served as vice-president of the ISASI Mid-Atlantic Regional Chapter for 15 years before his election as its president. He is active in the Reachout Workshop program, guides the corporate sponsorship program for the Society's annual seminar, and was awarded the 2002 ISASI Jerome F. Lederer Award.


Ron Schleede

Schleede retired from the NTSB in July 2000, after 28 years as an investigator and senior manager. In an exchange program, he served as director of air investigations at the Transportation Safety Board of Canada from December 1999 to June 2000. He is currently an independent consultant in international aviation safety, a contract instructor and member of the Advisory Board of the Southern California Safety Institute, and a member of the International Advisory Committee of the Flight Safety Foundation.

Mayes has been a member of ISASI since 1978. He served as ISASI vice-president for three terms concluding in 2002. He has also served as chairman of the ISASI Flight Recorder Working Group and Australian councillor. He also is an active member of Reachout and was an instrumental member of the ISASI 1991 and 2004 annual seminar committees. He has been involved with organising the programs of the biennial Australasian Safety Seminars in Australia since their inception in 1992.


Paul Mayes

He is currently manager of safety investigations and analysis for the Cobham Group Operations in Australia and Papua, New Guinea. He is also a Fellow of the Royal Aeronautical Society and a chartered engineer, a flight instructor, and holds an ATPL. He served for 21 years as air safety investigator with the Bureau of Air Safety Investigation, Australia, including head of air safety investigations, head of safety systems and analysis, and was with Air New Zealand in Auckland, New Zealand, where he held senior safety management positions including aviation safety advisor for 8 years. ◆

AAIB Singapore Scores High with First IAI Forum

With strong support from the International Civil Aviation Organization (ICAO), ISASI, the Flight Safety Foundation (FSF), and the European Civil Aviation Conference (ECAC), the Air Accident Investigation Bureau of Singapore (AAIB Singapore) organized a very successful Inaugural International Accident Investigation (IAI) Forum at the Singapore Aviation Academy April 21-23, 2010.

The Forum was attended by some 160 participants and speakers from about 30 ICAO Member States. The Forum theme, "Investigation in the New State Safety Program (SSP) Environment," brought topics such as SSP, recent amendments to ICAO's standards for international investigation, international cooperation, challenges in major accidents, and sharing and protection of safety information.

The panel discussions were spontaneous and participation was high. Many agreed that the IAI Forum was an excellent platform for interaction and discussion of ICAO matters and for raising questions on various AIG issues. Attendees also agreed that it provided

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Ariel Shocron, Technical Department Member

Individual
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Armstrong, Gordon, W., Newstead, OLD, Australia
Atadja, Raynold, S., Daytona Beach, FL, USA
Bergnach, Stefano, Buttrio, Italy
Bergstrand, Anders, Linkoping, Sweden
Brabant, Steven, J., Winnipeg, MB, Canada
Cavannagh, Douglas, G., Singapore, Republic of Singapore
Dudzinski, Michael, A., Oklahoma City, OK, USA
Duprie, Terry, L., Lake Charles, LA, USA
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Jones, Logan, P., Toulouse, France
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Shanney, Joseph, M., DuPont, WA, USA
Strand, Fredrik, M., Jakobsli, Norway
Viola, James, A., Alexandria, VA, USA
Watt, James, C., Kennesaw, GA, USA
Western, Ron, J., Winnipeg, Canada ◆

opportunities for networking and building rapport for future cooperation.

Vincent Galotti, deputy director of ICAO's Air Navigation Bureau, delivered the keynote speech, and Marcus Costa, chief of ICAO's Accident Investigation and Prevention (AIG) Section, spoke about the recent Annex 13 amendments.

Although unable to attend the IAI Forum in person, Nancy Graham, director of ICAO's Air Navigation Bureau, addressed the Forum through a prerecorded video message. In her message, she affirmed ICAO's support for the Forum series and that ICAO will use the IAI Forum as a platform to interact with investigation officials from ICAO Member States.

Paul-Louis Arslanian, ex-director of BEA, was honored for his dedication and contribution to the international accident investigation scene with the presentation of a plaque of appreciation to his representative. Arslanian was unable to attend the Forum because of the flight disruption caused by volcanic ash clouds over Europe.

The AAIB notes that its event will be held once every 3-5 years in Singapore. The next IAI Forum is set for 2013. ◆

New Zealand SASI Elects Officers

The New Zealand Society has held its election and seated existing officers to new positions.

Former Vice-President Alan Moselen, an air safety investigator with the Civil Aviation Authority of New Zealand, was elected to the president's office. He succeeded Peter Williams, an air accident investigator with the Transport Accident Investigation Commission (TAIC), who became vice-president. Russell Kennedy, a flight safety officer with RNZAF, was reelected to the secretary/treasurer position.

Alan Moselen

Moselen trained as an airframe fitter in the RNZAF, working on C130 Hercules and P3 Orion aircraft. He joined Air New Zealand as a LAME and worked on DC-10s and DC-8s. In 1979 he began flight engineer training and went on to crew DC-10s, DC-8s, B-727-200s, and B-747-200s for 20 years. In 1999 he became a safety investigator with Air New Zealand and has been an investigator with the NZCAA since 2001 and an ISASI member since 2000. He has a diploma in business studies and holds a current commercial pilot license and has held a single-pilot multiengine instrument rating. He is a member of Rotary International and the Royal Aeronautical Society. Al is married with two daughters. For relaxation, he enjoys golf, fishing, and the challenge of improving his BBQ chef performance. ◆

ANZSASI 2010 Seminar Well Attended

The annual Australia and New Zealand Societies co-hosted seminar recorded more than 100 participants, including representatives from Indonesia and Europe. Seminar planners selected a fitting venue for this air safety investigators' opening reception event: Aviation Hall at the Australian War Memorial, with appropriate videos playing on the walls and aircraft display all around.

ATSB Commissioner Martin Dolan gave the keynote address, followed by the annual Ron Chippindale Memorial Lecture presented by Paul Mayes on developments in safety investigation. Other topics included cultural considerations, lessons from an RNZAF investigation, air services safety systems, bird hazard mitigation, adhesive failure assessment, and airline investigations.

The seminar concluded with excellent presentations on SMS, complex investigations, predicting pilots risk behavior, HFACS, fiber composite aircraft, private aircraft operations, the Blackhawk A25-221 fatal accident, and HF in minimization of error in maintenance. Presentations from the seminar are available at the ASASI website: www.asasi.org.

ASASI announced its thanks to seminar sponsors for their generous support. ◆

GASIG Working Group Gains New Chair

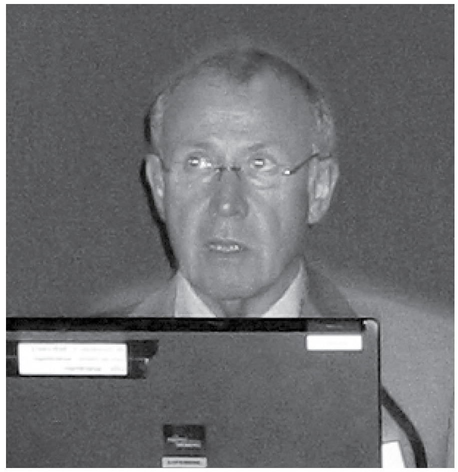
Marcus A. Costa has accepted President Frank Del Gandio's appointment as the chairman of the Society's Government Air Safety Investigators Group (GASIG) Working Group. Marcus is chief of the Accident Investigation and Prevention Section, ICAO headquarters.

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

As chairman, he will establish the agenda, meeting dates, and locations and procedures of the Working Group. Responsibilities of the Working Group include

- promoting the exchange of air safety investigation information.
- promoting collaboration to avoid the independent parallel efforts toward the same end.
- providing and encouraging the proactive approach to air safety investigation through the exchange of information on research, research techniques, and special studies.
- promoting interaction between safety professionals within the aviation industry.
- promoting the investigation by government air safety organization of accidents and incidents for accident prevention purposes only. ◆

European Society Conducts Third Annual Seminar



European Society President Dave King welcomes attendees.

The European Society of Air Safety Investigators held its third seminar in Toulouse, France, April 29-30. The event, hosted by Ecole National de l'Aviation Civle (ENAC) on the outskirts of Toulouse, was attended by more than 90 persons. As in previous years, the theme of the seminar was focused on the technical challenges and current European issues facing investigators.

Anne Evans, European councillor, reported that "There were presentations from EASA on the ongoing European developments in air safety. Paul Troadec, the new head of the French Bureau d'Enquetes et d'Analyses (BEA), spoke of the challenges ahead for his organization. The BEA gave an interesting brief on the AF447 loss and succinctly captured the complexities and challenges of the underwater search efforts by reminding us that the underwater locater beacons have an effective range of some 2,000 m while the ocean floor was at a depth of some 3,300 m. In order to help delegates appreciate the difficulties in locating the wreckage they were shown a map of the Swiss Alps with a circle of a 40-mile radius superimposed on it and asked to imagine that it was a topographical map of the search area except it was submersed at a depth of 3,000 m. Investigators from the UK Air Accidents Investigation Branch (AAIB) gave two fascinating presentations on the recent North Sea helicopter accidents, while the UK military representative gave us an insight into the unique challenges the military faces while conducting 'in theater' accident investigations."

The ESASI planning committee expressed its gratitude for all the local arrangements to Marc Houalla of ENAC for hosting the event, to Martine Del Bono and Nathalie Dandou for all their tireless work, and to Yannick Malinge of Airbus. ◆

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Administration des Enquêtes Techniques (Luxembourg)
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AeroVeritas Aviation Safety Consulting, Ltd.
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WHO'S WHO

Republic of Indonesia's National Transportation Safety Committee (NTSC)

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

The Republic of Indonesia has been a member of the International Civil Aviation Organization since April 27, 1950. Based on the Aviation Act No. 15/1992, Chapters 34 and 35, the Republic's president formalized the establishment of the Komite Nasional Keselamatan Transportasi (KNKT) or the National Transportation Safety Committee (NTSC) through Presidential Decree No. 105/1999, dated Sept. 1, 1999.

The KNKT/NTSC is an operationally independent institution within the Ministry of Transportation (MOT) and is responsible directly to the minister of transportation. As a reflection of its operational independence, the chairperson of the KNKT/NTSC is always selected from outside the MOT, even though the chairperson is appointed by the minister through the Minister of Transportation decree. The current chairperson of KNKT/NTSC, Tatang Kurniadi, was an Air Force officer. His appointment was effective March 5, 2007.

The KNKT/NTSC conducts selected

investigations of transportation mishaps (aviation, maritime, railway, and road transportation) and develops research and studies, as necessary, to identify possible safety deficiencies and to improve transportation safety performances.

The objective of the Committee's investigations is to determine when, what, who, how, and why transportation accidents occurred. Investigation reports are provided to promote aviation safety; in no case is the report intended to imply blame, judicial process, and liability.

Based on the new Aviation Act No. 1/2009, dated Jan. 12, 2009, the KNKT/NTSC, on Jan. 12, 2011, will be directly responsible to the president of the Republic of Indonesia.

Presidential Decree No. 105/1999 provides the NTSC chairman with a secretariat to help with all administration and three accident investigation subcommittees

1. Subcommittee of Aircraft Accident Investigation,
2. Subcommittee of Marine Accident Investigation, and
3. Subcommittee of Land Transport Accident Investigation.

The Subcommittee of Land Transport Accident Investigation is divided into two sub subcommittees: Sub Subcommittee of Railway Accident Investigation and Sub Subcommittee of Road Accident Investigation. ◆