ISASI FORUM

"Air Safety Through Investigation"

APRIL–JUNE 2005

CONTENTS

FEATURES

DEPARTMENTS

ABOUT THE COVER

Water salvage recovery operations of China Airlines Flight C1611 (Boeing 747-200B), which on May 25, 2002, experienced an inflight breakup near Penghu Islands, 23 nautical miles west of Taiwan. All 206 person aboard the aircraft perished. The investigation was led by the Aviation Safety Council Taiwan. Photo courtesy ASC.

ISASI FORUM
"Air Safety Through Investigation"

Volume 38, Number 2

Publisher Frank Del Gandio
Editorial Advisor Richard B. Stone
Editor Esperison Martinez
Design Editor William A. Ford
Associate Editor Susan Fager
Annual Report Editor Ron Schleede

ISASI Forum (ISSN 1088-8128) is published quarterly by International Society of Air Safety Investigators. Opinions expressed by authors do not necessarily represent official ISASI position or policy.

Editorial Offices: Park Center, 107 East Holly Avenue, Suite 11, Sterling, VA 20164-5405. Telephone (703) 430-9668. Fax (703) 430-4970. E-mail address isasi@erols.com; for editor, espmart@comcast.net. Internet website: www.isasi.org. ISASI Forum is not responsible for unsolicited manuscripts, photographs, or other materials. Unsolicited materials will be returned only if submitted with a self-addressed, stamped envelope. *ISASI Forum* reserves the right to reject, delete, summarize, or edit for space considerations any submitted article. To facilitate editorial production processes, American-English spelling of words will be used.

Publisher's Editorial Profile: *ISASI Forum* is printed in the United States and published for professional air safety investigators who are members of the International Society of Air Safety Investigators. Editorial content emphasizes accident investigation findings, investigative techniques and experiences, regulatory issues, industry accident prevention developments, and ISASI and member involvement and information.

Subscriptions: Subscription to members is provided as a portion of dues. Rate for nonmembers is US$24 and for libraries and schools US$20. For subscription information, call (703) 430-9668. Additional or replacement *ISASI Forum* issues: members US$3, nonmembers US$6.

AIR SAFETY INVESTIGATORS
INCORPORATED AUGUST 31, 1964

PRESIDENT'S VIEW

ISASI's Silent Benefactors

By Frank Del Gandio, President

Small membership, nonprofit organizations such as ours depend almost entirely upon its members' generosity in giving their time, knowledge, and in-house resources, to say nothing of prompt dues payments, to make the organization's programs successful—indeed, to initiate, to establish, and to operate those same programs. And to all of you, your International Council members and I say a gargantuan "Thank You!"

Today, I would also like to recognize those we call "silent benefactors." These members are those among you who go one step beyond the norm—those of you who so willingly, and without personal prompting, send cash contribution to help the Society fund its needs and its programs. These funds come to us earmarked for the recently created memorial scholarship, for the central treasury, or for some other program the contributor may hold close to the heart. Whatever the case may be, the monies are directed to that cause for which contributed.

Because we are in the application submission/selection time frame, let me give an overview of the Rudolph Kapustin Memorial Scholarship Fund, which your Society established in 2002 and which to date has selected three recipients. Notably, the Dutch Transport Safety Board has placed one of these recipients in its investigative workforce.

The family of Rudy Kapustin, a long-term ISASI safety stalwart whose accident investigatory skills brought him worldwide renown as an investigator working for the National Transportation Safety Board (USA), initiated the scholarship idea. Rudy's family wanted his heritage of accident investigation to live on and believed that introducing aviation-oriented students to the profession was the way to accomplish this. Your ISASI Council further defined and established the scholarship program, which is dedicated to the memory of *all* deceased ISASI members but carries Rudy's name for his sterling contributions.

The purpose of the scholarship is to encourage and assist college-level students interested in the field of aviation safety and aircraft occurrence investigation. To be eligible, a student must be enrolled as a full-time student in an ISASI-recognized college-level education program. The program stipulates various areas of study that must be addressed and focuses on aircraft accident and incidents investigation and aviation safety (see *Forum* October-December 2004, page 27).

A scholarship of $1,500 is provided to the selectee, and he/she must agree to attend the next ISASI annual seminar. Scholarship funds are intended to help offset the costs of the ISASI seminar registration fees, travel, and lodging. Here again, some "silent benefactors" have unexpectedly come into play. Because we meet in worldwide locations, the scholarship award most likely would be insufficient to cover air travel and related costs to distant places from the recipient's home base. Such was the case in last year's Australia seminar. Emirates Airways, platinum sponsor of the seminar, stepped in and eased costs by donating earned (platinum) credits to the selectee.

Another silent benefactor, Southern California Safety Institute—a zealous ISASI corporate member—has instituted an add-on to the Kapustin Memorial Scholarship. The prestigious and ardent safety school is providing each scholarship winner tuition-free attendance at its renowned aircraft accident investigation course or at any one of the other SCSI scheduled investigation courses. Unfortunately, SCSI is unable to fund travel or accommodations as part of its supplied benefit. One of our scholars has already taken advantage of this generous tuition-free gift. The scholar must meet all other expenses on his/her own.

I leave you with these thoughts: First, ISASI needs funds to continue this and other worthwhile programs. All donations to ISASI are tax-deductible (U.S.) and donors receive a receipt for contributions. Second, ISASI is not receiving near enough applications from students. Help us spread the word of the scholarship's availability. Think about arranging to give a presentation at an aviation school on ISASI, aviation safety, and the scholarship program. Students at such schools are extremely important to ISASI and the aviation community. With help from silent benefactors, they will fulfill their destined role of maintaining and improving aviation safety through investigation. ◆

Contributors

Year 2005
Contributors:
General Fund
Albert Abramson, Esquire
William Allen
James Angus
Sameer Bagsair
Ludwig Benner, Jr.
David Berger
Harry Black
Bernard Brown
Dan Driggs
John Enders
Theodore Faber
John Gill
Wyrewood Gowell
George Grebezs
Joseph Hall
David Hessler
B. Victor Hewes
Thomas Howell
Donald Hunt
Michael Hynes
Jose Juncosa
Ram Kursh
Robert LaTulipe
Thomas Laughlin, Jr.
Tom McCarthy
Fred McGowan
Charles Mercer
Robert Orr
Austin Pacher
Robert Patterson
Gilbert Queitzsch, Jr.
Finn Rasmussen
Joseph Reynolds, P.E.
Carol Roberts
Rafael Sabando
Max Saint-Germain
Daniel Sayres
Richard Snyder
John Stefanki
Richard Stone
Neal Thomas
George Tsimekas
Daniel van Rijckevorsel
Tolford (Tod) Young
AirTran Airways/ Jean-Pierre Dagon

Year 2004 Contributors:
Memorial Scholarship Fund
Theodore J. Banick
Frank Del Gandio
Kapustin Family
Stephanie A. Moray, CPA
John W. Purvis
Ron Schleede
John X. Stefanki
Association of Professional Flight Attendants
Mid-Atlantic Regional Chapter—U.S. Society

V.P.'s Corner

Internet Speeds Investigative Results

By Ron Schleede, Vice-President

In previous writings, I mentioned my continuing concerns about the lack of timely and accurate communication of safety information and lessons learned from investigations of accidents and incidents. It was my experience over the past 30-plus years that information critical to preventing future accidents was not getting to all of the right persons and/or organizations. Further, lessons learned by investigators regarding new and innovative investigation techniques were not always available to other investigators in a timely or systemic manner.

I was often made aware that there was a strong desire by pilots, mechanics, flight attendants, air traffic controllers, investigators, safety managers, etc., to learn about the progress and findings of investigations, particularly when the occurrence involved their particular area of work and responsibilities in the aviation system. Unfortunately, they most often had to rely on news media reports and "filtered" or "twisted" reports from less-than-objective sources. Most interested persons had no timely access to objective investigation factual data or final reports and safety recommendations.

I was also often aware that, other than ISASI seminars, *ISASI Forum,* and periodic ICAO-sponsored seminars, there were no systemic means available for air safety investigators to gain timely insight into other investigators' new and innovative investigation techniques and other lessons learned.

Part of the problems of the past can be attributed to archaic means of distributing information. For example, reports and other publications were produced in hard copy only and made available to a limited number of recipients, long after the date of the occurrence. Those problems should no longer exist because of the development of Internet websites and electronic newsletters, etc., that provide the capability for worldwide distribution—virtually in real time—to all potential users. For example, the recent public release of a few high-visibility accident reports by independent investigative agencies included electronic notification of the releases and links to the press releases, investigator factual reports, and final reports.

Many of us now learn about such releases within hours by means of the Flight Safety information (www.fsinfo.org) daily electronic newsletter distributed as an e-mail from Curt Lewis, ISASI U.S. Councilor. Also, some investigative agencies and a few other organizations now provide electronic notification of newly released reports and other information for subscribers to their websites, a service I certainly appreciate and use on a daily basis.

Of course, Internet notification and distribution of accident/incident information is not new, although it has really only emerged and grown in scope in the past 10 years or so. This situation prompted me to do some Internet surfing to determine what resources were available to air safety investigators and safety managers. I found numerous resources; however, I could not locate any comprehensive lists, without considerable effort. Therefore, I decided to generate a list of Internet websites that might be useful to members of ISASI and others. I define "useful" in this context to mean: 1) useful for timely distribution of safety information and 2) useful for disseminating investigative lessons learned, so other investigators may benefit from the work of other investigators.

Below are links that I have placed in my "favorites." I hope that others will find them useful. There are four groups of links: 1) government investigation agencies, 2) accident/incident databases, statistics, accident reports, and current and historical material, including laws and regulations, 3) regional and international organizations, and 4) confidential incident reporting programs *(useful for investigators to query for similar occurrences without compromising privacy issues)* . Some of the sites offer free subscription services whereby subscribers receive electronic notification (e-mail) when new material is added to the site, while some of them provide periodic electronic newsletters.

I find electronic notification and newsletter services very useful, and I would urge that more organizations incorporate these services in the future, particularly investigation agencies, which are in a position to publish objective information. Internet notifications and updates provide an excellent means to issue interim factual information, highlight interim safety actions taken or needed, and to outline the progress of the investigation, including investigative methods and techniques being explored. These services enable the dissemination of lessons learned and are an excellent resource for air safety investigators to learn about other investigators' work during the entire process of an investigation.

I am sure that I have overlooked additional sites and apologize in advance. If any readers are aware of sites that should be added to the lists or if there are mistakes in the lists provided herein, please send me a note at RonSchleede@cox.net and copy to ISASI@erols.com so that we can maintain a current and complete list at the ISASI office. We also may reprint the list in future *Forums* and will place them on the ISASI website.

Some of the following links are in the local language; however, they include the option to open an English language version of the site. Some offer other ICAO language access.

Government Investigation Agencies

Australia—Transport Safety Bureau
www.atsb.gov.au
(continued on page 30)

Managing Mental Fatigue

Traditionally regulation rule sets have managed fatigue based on physical fatigue attributes rather than those of mental fatigue. This approach incorrectly assumes that the determinants of mental fatigue are similar to those of physical fatigue. A potential alternative is a shift from prescriptive hours of service limitations toward a broader safety management system approach.

By Professor Drew Dawson and Kirsty McCullough, University of South Australia

(This article was adapted, with permission, from the author's presentation entitled Managing Fatigue as an Integral Part of a Fatigue Risk Management System, *presented at the ISASI 2004 seminar held in Australia's Gold Coast region Aug. 30 to Sept. 2, 2004, which carried the theme "Investigate, Communicate, and Educate." The full presentation including cited references index is on the ISASI website at www.isasi.org.—Editor)*

Mental fatigue associated with working conditions has been identified as a major occupational health and safety risk in most developed nations. In part, this has been driven by scientific evidence indicating an association between increasing fatigue and declines in cognitive function, impaired performance, increasing error rates, and ultimately, reduced safety. Accordingly, governments and safety professionals have argued that mental fatigue is an identifiable workplace hazard that warrants regulatory attention (all references to fatigue imply mental fatigue unless specifically indicated otherwise).

Traditionally, efforts in fatigue risk management have attempted to reduce fatigue-related risk through compliance with an agreed set of rules governing hours of work. In the U.S. these are generally referred to as the hours of service (HOS) rule. At the most fundamental level, regulation has involved the prescription of maximum shift and minimum break durations for individual shifts or work periods. In addition, some industries and organizations have supplemented individual shift rules with supra-shift rules that further restrict the total number of sequential shifts or cumulative hours worked in a given period (e.g., week, month, or year). These limitations have typically been imposed coercively via a regulatory body or "voluntarily" through a labor contract.

The traditional prescriptive HOS approach most probably derives from earlier regulatory approaches for managing physical rather than mental fatigue. In the early part of the 20th century, occupational health and safety (OH&S) hazards related to physical fatigue were managed primarily by regulating the duration of work and non-work periods. Previous research had indicated that physical fatigue accumulates and discharges in a broadly monotonic manner with respect to time. As such, managing physical fatigue by limiting work hours and break periods was both scientifically defensible and operationally practical.

It is common to use analogous approaches for the regulation of a new hazard. However, in the case of mental fatigue, this approach incorrectly assumes that the determinants of mental fatigue are similar to those of physical fatigue. While it is true that mental fatigue does, in part, accumulate in a relatively linear manner, there are significant additional non-linearities driving the dynamics of fatigue and recovery processes for mental fatigue.

Circadian biology, for example, influences the dynamics of fatigue accumulation and recovery in a way that produces significant non-linearities. For example, prescriptive limitations on shift duration generally assume that a break of a given length has a uniform recovery value with respect to mental fatigue. While this may be relatively true with respect to physical fatigue, it is demonstrably not the case with respect to mental fatigue. Indeed, providing the same length of time off during the subjective day, as opposed to subjective night, will result in a significantly reduced amount of recovery sleep.

In our opinion, estimating the level of mental fatigue associated with a given pattern of work is linked more to the timing and duration of sleep and wake within the break, rather than the duration of the break alone. Although there is clear scientific evidence to support this notion, few regulatory models acknowledge it explicitly. As depicted in Figure 1, it is our view that regulatory models based only on shift duration are unlikely to produce congruence between what is safe and what is permitted

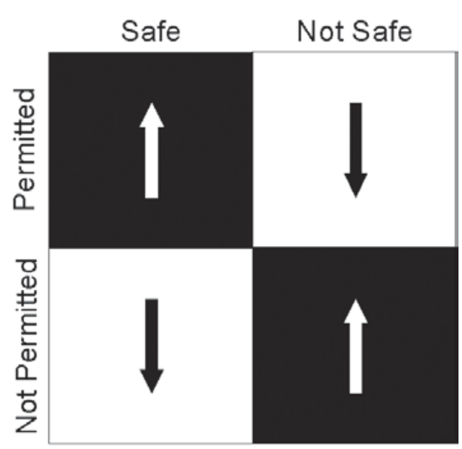


Figure 1: Effective regulatory models should provide congruence between what is safe and permitted as well as what is unsafe and not permitted. This is often not the reality with traditional prescriptive HOS regulatory approaches.

Professor Drew Dawson *is currently the director of the Centre for Sleep Research at the University of South Australia. He is nationally and internationally recognized for his contributions to the scientific community and to industry in the areas of organizational psychology and human factors, industrial relations negotiations, and the human implications of hours of work. He has worked extensively with the aviation, manufacturing, retail, entertainment, transportation, and mining sectors in Australia and is internationally recognized as a consultant on fatigue in the workplace.*

No photo available

Kirsty McCullough *is a Ph.D. research student at the Centre of Sleep Research, University of South Australia. (The authors extend their thanks to Dr. Angela Baker, Dr. Sally Ferguson, and Dr. Adam Fletcher for their comments and input to the presented work.)*

and what is unsafe and not permitted.

The relationship between the recovery value of non-work periods (vis-à-vis mental fatigue) and the actual amount of sleep obtained has become increasingly complex in recent years. In addition to the biological limitations of this approach, increases in total working hours, lengthening of shift durations from 8 to 12 hours, and concurrent reductions in breaks from 16 to 12 hours have significantly restricted the opportunity for sleep. Furthermore, changes in workforce demographics and the social use of time in and outside the workplace have exerted additional downward pressure on the amount of time individuals choose to allocate for sleep.

Recent trends

As noted, many of the current approaches to mental fatigue management have focused on hours of service. However, these approaches may be of limited value in the systematic management of fatigue-related risk. This has been particularly highlighted by recent research and policy initiatives in the U.S., Australia, Canada, and New Zealand. In these jurisdictions, there is an emerging, albeit controversial, view that alternatives to prescriptive models of fatigue management might be more usefully explored. Moreover, relative to traditional prescriptive approaches, that alternative approaches may hold significant potential for improved safety and greater operational flexibility.

To date, most alternative approaches to prescriptive HOS embed fatigue management within the general context of a safety management system (SMS) and, arguably, provide a more defensible conceptual and scientific basis for managing fatigue-related risk as well as the potential for greater operational flexibility. This is in marked contrast to current HOS models whose roots are inextricably bound up in the history of their labor relation's process, where the primacy of short-term financial factors has frequently distorted safety outcomes.

Despite the theoretical attraction of alternative approaches to prescriptive HOS, many commentators have, with good reason, expressed reservations about their actual benefits in practice. For example, an increase in the flexibility of the HOS regulation has often been interpreted (by employees and their representatives) as a disingenuous attempt to deregulate or subvert current or proposed HOS rules. Conversely, tightening of the HOS regulation to reduce fatigue has sometimes been interpreted (by employer groups and their advocates) as a disingenuous attempt to leverage better pay and conditions, rather than improve safety.

For the last few years, our research group has conducted extensive consultation with industry stakeholders and regulators in several countries and in a variety of industries to understand how fatigue might best be managed using alternative approaches. In doing so, we have canvassed two broad approaches. First, the modification of traditional prescriptive HOS regulations to ensure they address matters related to legal and scientific defensibility as well as operational flexibility. Second, we have considered alternative regulatory models that might be used as the basis of a new approach that meets the previously mentioned goals of scientific defensibility and flexibility.

Our objective was to establish a well-structured view of how fatigue might best be regulated, as well as the most appropriate way in which such reform might be achieved at the practical level.

On the basis of discussions with industry, we believe there is an emerging consensual view that

- given the diversity of modern organizational practice, a traditional prescriptive HOS approach may not be the most appropriate or only way to manage fatigue-related risk.
- alternative approaches to prescriptive HOS for fatigue management have significant potential to improve operational flexibility and safety.
- alternative approaches also hold significant potential to be abused by organizations or individuals for whom regulatory enforcement is a low-probability event and/or the consequences of non-compliance are trivial.
- alternative approaches will require a significant maturation in organizational and regulatory culture if they are to be successful in reducing fatigue-related risks to the community.
- there should be a standard methodology of measuring outcomes and program efficacy.

An alternative approach

On the basis of discussions with key industry and regulatory stakeholders, our view is that the most appropriate solution for effective fatigue management is to expand the regulatory framework from a prescriptive HOS approach and to permit certain organizations to use an SMS approach. This would be based on existing occupational safety and health standards, practices, and principles (e.g., Canadian OH&S act; the OHSAS 18001; the Australian/New Zealand standard for occupational health and safety management systems AS/NZS 4801:2001). From this perspective, fatigue would be managed as an "identifiable OH&S hazard" and would be one part of a more general organizational SMS.

It may also be useful to expand the use of a prescription/compliance perspective to include approaches that emphasize outcomes. That is, rather than prescribing one universal rule set, the management of safety risks could be effectively achieved in a variety of organization- or industry-specific ways. In doing so, each organization or industry would be responsible for developing a fatigue risk management "code-of-practice," and through formal review processes, continue to refine and improve the safety environment vis-à-vis fatigue. According to this view, the role of regulation would be to legislate for an outcome (e.g., a reduction in fatigue-related risk) rather than assume that compliance with a prescriptive HOS standard implies, and ensures, a given level of safety.

To date, most examples of outcome-based systems for fatigue risk management have been developed within the transportation sector. These include the Transitional Fatigue Management Program, developed by Queensland Transport; the Australian Civil Aviation Safety Authority (CASA) Fatigue Risk Management System; fatigue risk management programs of a number of Australian rail organizations; and the North American Federal Railroad Administration. In addition, air traffic controllers in both Australia and New Zealand have used hybrid prescription/outcome-based approaches for several years.

Initial pilot studies or projects using outcome-based fatigue risk management have had mixed results with early evaluations suggesting the approach has considerable potential but significant risks associated with poor enforcement and assessment. Furthermore, there has been minimal work assessing their longer-term efficacy or enforceability. Until such projects mature and evaluative research is published, the scientific safety community should continue to develop and refine the conceptual framework that underlies such systems.

Traditionally, and particularly within Europe, it is common for policymakers (often in conjunction with relevant researchers) to develop recommendations on what are considered acceptable shifts and/or patterns of work. For example, forward rotating shifts, maximum number of sequential working days, length of shift (8, 10, or 12 hours), and minimum number of days off required for recovery. These, in turn, have been published and subsequently held up as *de facto* standard. Using these standards, shifts are constructed as either stable roster patterns or flexible rosters that are constructed from preapproved scheduling features (e.g., no more than four night shifts in a row, or no break less than 8 hours). Using this approach, a roster or schedule is deemed acceptable if it does not contain any unapproved features. Advantage? The roster is treated as an integrated whole. Disadvantage? It is difficult to generalize to novel or innovative rosters or schedules.

Furthermore, the approach fails to identify individual differences in fatigue-related risk. This approach assumes, at least implicitly, that the effects of a given shift system are similar for all individuals. That is, it fails to address potential interactions between the shift system and employee demographics. A final criticism is that it fails to distinguish between work-related causes of fatigue and fatigue due to non-work-related causes. That is, it is possible for an individual to arrive at work fatigued due to inappropriate use of an adequate recovery period.

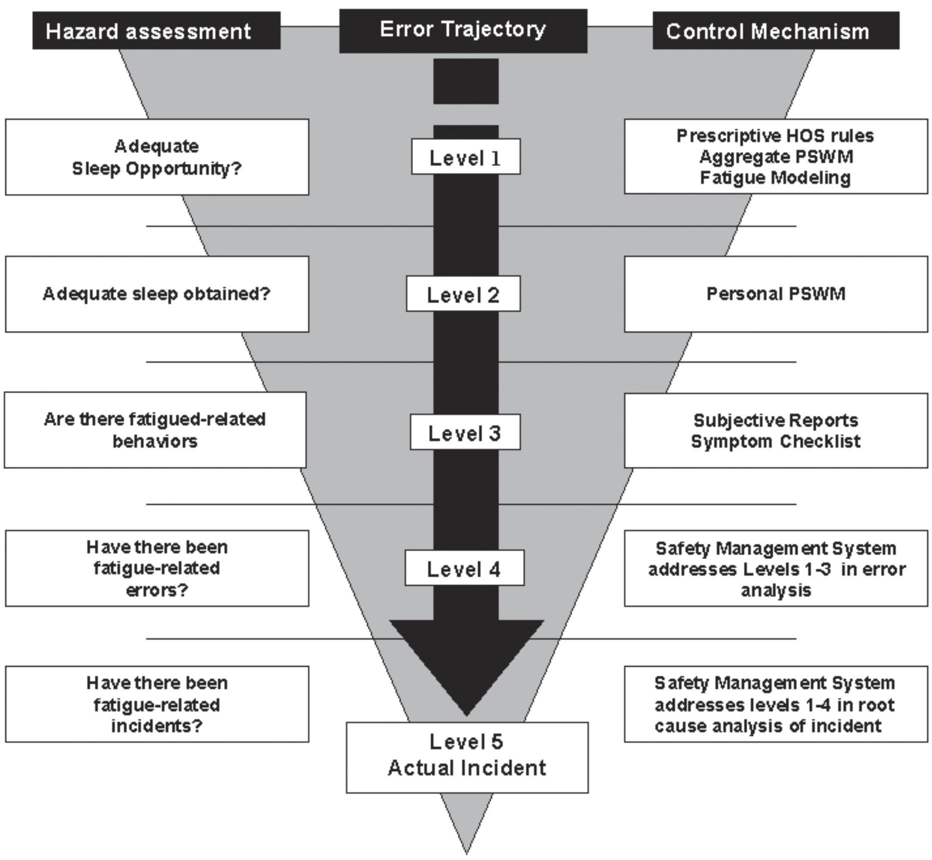


Figure 2: Fatigue risk trajectory. There are multiple layers that precede a fatigue-related incident, for which there are identifiable hazards and controls. An effective fatigue risk management system should attempt to manage each layer of risk. (PSWM—Prior sleep/wake model).

To gain the generalizability and flexibility of a feature-based approach, without the disadvantages of inadvertent interaction between features, let's look at a novel methodology for defining the degree of fatigue likely to be associated with a particular roster or schedule. Before addressing the details of that approach, it is particularly important to understand the way fatigue management has been traditionally approached—notably, that it has been addressed primarily as a labor relations, rather than a safety management, issue.

A conceptual framework

Most regulatory frameworks to date have not considered mental fatigue as a hazard to be managed as part of a safety management system. Instead, it has been managed through compliance with a set of externally imposed prescriptive rules. While this is understandable, there is no reason, other than historical bias, that precludes the use of the same SMS principles that would apply for any other identifiable safety hazard.

Furthermore, this conceptual framework would provide a sounder conceptual basis for managing fatigue-related risk fatigue management. In addition, it could easily sit within the pre-existing and emerging SMS frameworks currently advocated by regulators and safety professionals.

This methodology can be represented using Reason's (1997) hazard-control framework. A fatigue-related accident or incident (FRI) is seen as only the final point of a longer causal chain of events or "error trajectory." An examination of the error trajectory associated with an FRI will indicate that there are four levels of antecedent event common to any FRI.

From Figure 2, an FRI is merely the end point of a causal chain of events or "error trajectory" and is always preceded by a common sequence of event classifications that lead to the actual incident. Thus, an FRI is always preceded by a fatigue-related error (FRE). Each FRE, in turn, will be associated with an individual in a fatigued state, exhibiting fatigue-related symptomology or behaviors. The fatigued state in the individual will, in turn, be preceded by insufficient recovery sleep or excessive wakefulness. Insufficient sleep or excessive wakefulness will be caused by either (a) insufficient recovery sleep during an adequate break (e.g., fail to obtain sufficient sleep for reasons beyond their control, choosing to engage in non-sleep activities, or a sleep disorder) or (b) by an inadequate break. (e.g., the roster or schedule did not provide an adequate opportunity for sufficient sleep).

Each of the four steps in the general error trajectory for an FRI provides the opportunity to identify potential incidents and, more importantly, the presence (or absence) of appropriate control mechanisms in the system. It is also often the case that many more potential incidents (i.e., "near misses") will occur than actual incidents and that these could, if monitored, provide a significant opportunity to identify fatigue-related risk and to modify organizational process prior to an actual FRI.

Potentially, this framework would enable the identification of the root causes of many potential FRIs in a logical and consistent manner. In addition, effective hazard control measures for fatigue-related risk at each "level" of control can systematically be organized and implemented using a systems-based approach. The figure also implies that the incidence of fatigue-related incidents can be reduced by more coordinated or integrated control of the antecedent events or behaviors that constitute potential or "latent" failures of the safety system.

Effective management of fatigue-related risk requires a fatigue risk management system (FRMS) that implements task and organizationally appropriate control mechanisms for each point in the theoretical error trajectory. Where an organization fails to develop appropriate controls at each level of the hierarchy, it is unlikely that, overall, the system will be well-defended against fatigue-related incidents.

The regulatory approach

Figure 2 also provides a useful way of understanding (1) the piecemeal and uncoordinated nature of many regulatory approaches to fatigue management to date and (2) why unintegrated approaches to managing fatigue-related risk (such as sole use of prescriptive HOS rules) may not be entirely successful.

In general, accident investigations have focused primarily on later segments of the error trajectory when trying to identify whether fatigue was a contributing factor. Conversely, when framing regulatory responses to fatigue-related incidents (as a control measure), there have rarely been systematic attempts to address all levels and few, if any, directed to lower levels of the error trajectory. In doing so, policymakers have assumed that compliance with prescriptive HOS rule sets and other relevant labor agreements constitutes an effective control measure for fatigue-related risk. As such, even if individual organizations were to achieve explicit compliance (admittedly a farcical assumption in many industries), they implicitly (and erroneously) assume that

- a rule set can determine reliably whether an individual will be fatigued (or not) and,
- individual employees always use an ostensibly adequate opportunity for sleep appropriately and obtain sufficient sleep.

Since, in many situations, these two assumptions are demonstrably untrue, an effective FRMS must provide additional levels of controls for those occasions when the preceding levels of control might prove ineffective.

As can be seen from recent alternative systems-approach initiatives, there can be very different intellectual and emotional perspectives on the appropriateness and relative merits of different control mechanisms at a single level of the diagram in Figure 2. For example, in recent years there has been considerable discussion as to the relative merits of fatigue modeling and the more traditional HOS approaches.

From the perspective in Figure 2, both are only Level 1 control strategies that attempt to ensure that employees are given, on average, an adequate opportunity to gain sufficient sleep. Since this is only a probabilistic determination and no hazard-control mechanism is perfect, neither will prevent all error trajectories in Figure 2 projecting beyond Level 1. Thus, a system with little or no hazard controls at Level 2 or beyond may be quite poorly defended against FREs. Similarly, in a system that has very effective hazard-control strategies at Levels 2-4, debates about the relative merits of different Level 1 strategies could arguably be considered moot.

A novel conceptual basis

Let's now look at a novel conceptual basis for the development of appropriate control mechanisms for fatigue-related hazards and the scientific justification for such an approach.

Figure 2 illustrates that an effective approach to fatigue management will require a variety of control measures applied at each of the four points on the error trajectory. Thus, an effective FRMS would require control procedures at Level 1 of the error trajectory that ensure employees are provided with an adequate opportunity for sleep. It would also require control procedures at Level 2 that ensure that employees who are given an adequate opportunity for sleep actually obtain it. At Level 3 we need to ensure that employees who obtained what is considered, on average, sufficient sleep are not experiencing actual fatigue-related behaviors (e.g., due to sleep disorders, non-work demands, or individual differences in sleep need). The use of symptom checklists or subjective fatigue scales is an example of control procedures at this level. Similarly, we would need control procedures at Level 4 to identify the occurrence of FRE that did not lead to an FRI. Finally, an effective FRMS would require an incident analysis and investigation procedure to identify those occasions when all the control mechanisms failed to prevent an FRI.

Editorial space does not permit addressing the development of appropriate control procedures at Level 3 and above. So, the focus will be on a novel conceptual framework for the design and implementation of control procedures at Levels 1 and 2 of the error trajectory outlined in Figure 2. That is, control methods for determining whether

- a roster or schedule provides, on average, an adequate opportunity to obtain sufficient sleep, and,
- if so, whether an individual has actually obtained sufficient sleep.

Existing efforts

Historically, the principal Level 1 control mechanism has been the development of prescriptive HOS rule systems that purport to provide adequate opportunity for sleep. In recent years there has been an emerging scientific and regulatory consensus that many of our prescriptive shift work rules do not provide a reliable control mechanism that prevents fatigued individuals from undertaking unsafe working practices. This is due primarily to a failure to distinguish between

- non-work and sleep time in determining the recovery value of time off, and
- the failure to take into account the time of day at which shifts or breaks occur.

As a consequence, there has been a strong move toward developing different approaches to ensure an adequate average opportunity to obtain sleep for fatigue risk management. Broadly speaking, these can be divided into two groups

- modified prescription, and
- fatigue modeling.

From a practical perspective, it is important to determine whether a given shift system, on average, enables an individual to report fit for duty. That is, whether the particular pattern of work provides adequate opportunity for sleep. Recently, fatigue modeling has provided an appealing alternative to traditional prescriptive approaches in that it appears more "scientific" and it provides a reliable method to determine whether a pattern of work adequately limits waking time and provides adequate opportunity for sleep. For a comprehensive review of existing models, see the 2004 issue of *Aviation, Space, and Environmental Medicine.*

While some of the models are extremely useful for predicting average levels of fatigue at the organizational level, they are not particularly useful for determining whether a given individual is fit for duty on a given occasion. Specifically, such approaches are unlikely to provide conclusive indications of whether an accident or incident was due to fatigue, because they can tell us nothing about individual behavior on a given day.

Thus, while modeling approaches to fatigue risk management represent a significant potential improvement in our capacity to assess general aspects of a schedule, they do not provide controls any higher than Level 1 in the error trajectory. Most importantly, they provide little or no guidance for determining the likelihood of fatigue and, therefore, fatigue-related risk on a day-to-day basis for individuals within the organization.

There have been some attempts to develop control mechanisms for fatigue at higher levels in the error trajectory. For example, in some regulatory environments individuals have been assigned the right and/or responsibility to override prescriptive guidelines where they believe it is appropriate (e.g., Civil Aviation Order 48). The difficulty with this requirement is the reliability of self-assessment of fatigue. Although people can estimate their level of fatigue or alertness with some degree of reliability, we have very little scientific evidence to support the notion that individuals can use this information to make reliable subjective judgments about the concomitant level of risk or safety and relative fitness for duty. It also ignores the very real potential for coercive financial, social, and operational pressures to distort effective decision-making in this area.

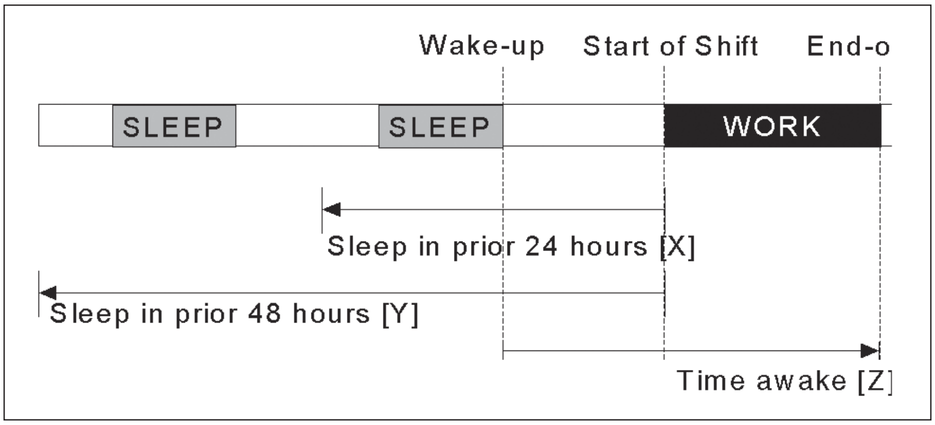


Figure 3: **Prior sleep wake model (PSWM). Fitness for work at Levels 1 and 2 of effective fatigue risk management can be determined by an algorithm that is comprised of three simple calculations: prior sleep in the last 24 hours, 48 hours, and length of wakefulness from awakening to end of work.**

In other jurisdictions, we have seen enthusiastic attempts to introduce the requirement to train and educate employees about fatigue. These initiatives, while well-intentioned, assume that training and education in itself will produce beneficial changes in individual and organizational safety behavior with respect to fatigue-related risk. Despite significant spending in this area, to date, there is little or no published evidence to support the hypothesis that improved knowledge of the determinants of fatigue and potential countermeasures leads to improved hazard control.

Given the shortcomings of fatigue modeling and subjective self-estimations of fatigue, we propose a behaviorally based methodology for assessing fatigue.

Proposed model

The following proposed model outlines methods for predicting average levels of fatigue at the organizational level, as well as control mechanisms for the more specific, day-to-day risk of fatigue at the individual level within organizations.

The first point is that a detailed understanding of the relationship between increasing fatigue and risk for many industries and occupations is not present. There is a significant body of laboratory research indicating that increasing fatigue is associated with increases in the probability and/or frequency of certain types of performance degradation on standard measures of neurobehavioral performance.

However, the best that can be said with particular regard to safety is that increasing fatigue is typically thought to be associated with increasing likelihood of error. Thus, the point where research can be used to clearly articulate the likelihood or typology of errors for specific tasks and/or workplace settings has not been reached, as of yet.

At best, suggestions can be made that based on the published literature

- error rates increase exponentially with linear increases in psychometric measures of fatigue.
- errors are broadly comparable in nature and frequency with other forms of impairment (e.g., alcohol intoxication).
- only general predications can be made about the susceptibility of certain types of tasks to fatigue-related error.

In view of the lack of a detailed understanding of workplace or task-specific risk associated with fatigue, any set of guidelines should be considered provisional, tentative, and subject to ongoing refinement on the basis of post-implementation evaluation.

With this caveat stated, we would suggest that knowledge of the frequency distribution of prior sleep and wake could form a rational basis for determining the level of fatigue an individual is likely to experience within a given shift.

Furthermore, there is potential for both individuals and organizations to use this information as the basis for rational decision-making with respect to mental fatigue-related risk. Within this framework, there are two main questions that should be asked. First, is the individual fit for duty and acceptably rested to commence work? The second question is predicated on the answer to the first. That is, if an individual is acceptably alert to commence work, for what period of time can he be reasonably expected to work before fatigue subsequently creates an unacceptable level of risk?

As a starting point for this decision, a rational FRMS should be based on prior sleep and wake rules, linked to an evaluation of the adequacy of prior sleep and wake. The reasons for this are straightforward.

- Unlike subjective estimates of fatigue, prior sleep and wake are observable and potentially verifiable determinants of fatigue.
- Prior sleep and wake provide a way of integrating individual and organizational measures of fatigue (Levels 1 and 2) since systems-based approaches can deal with probabilistic estimates of sleep and wakefulness, and individual employees can make clear determinations of individual amounts of actual prior sleep and wakefulness.
- Prior sleep and wake measures can be set or modified according to the risk profile associated with specific tasks or workgroups.

A simple algorithm based on the amount of sleep and wake experienced in the 48-hour period prior to commencing work can help determine whether an employee is likely to be fatigued and determine the required degree of hazard control.

The algorithm in Figure 3 is comprised of three simple calculations:

- ***Prior Sleep Threshold***—Prior to commencing work, an employee should determine whether he or she has obtained a) X hours sleep in the prior 24 hours, and b) Y hours sleep in the prior 48 hours.
- ***Prior Wake Threshold***—Prior to commencing work, an employee should determine whether the period from wake up to the end of shift exceeds the amount of sleep obtained in the 48 hours prior to commencing the shift.
- ***Hazard-Control Principle***—Where obtained sleep or wake does not meet the criteria above, then there is significant increase in the likelihood of a fatigue-related error and the organization should implement appropriate hazard-control procedures for the individual.

A critical aspect of the rules defined above is to create appropriate threshold values for the minimum sleep values for the prior 24 and 48 hours to commencing work and the amount of wakefulness that would be considered acceptable. Importantly, note that the thresholds could potentially vary as a function of fatigue-related risk within a workplace. For example, if a given task has either a greater susceptibility of fatigue-related error or there are significantly greater consequences of a fatigue-related error, the threshold values may be adjusted to a more conservative level.

From this perspective, fatigue-related accidents or incidents are seen as the final segment in a causal chain of events or error trajectory. Within the error trajectory there are four identifiable segments common to all fatigue-related incidents. At the earliest levels of the error trajectory are segments related to (1) the provision of an adequate opportunity to sleep and (2) appropriate use of a sleep opportunity (break period). This review shows a proposed novel methodology that enables organizations to take an integrated approach to determining whether they have appropriate control procedures at Level 1 or 2 of the proposed fatigue-related error trajectory.

The basis to this methodology is the prior sleep wake model (PSWM). The conceptual basis to this model is that fatigue is better estimated from prior sleep/wake behavior than from patterns of work. Using this model, an organization can define task-specific thresholds for sleep and wakefulness based on the amount of sleep obtained in the 24 and 48 hours prior to commencing work. Where aggregate or individual sleep/wake values fail to reach predesignated thresholds, the increased likelihood of fatigue would require a greater level of hazard control to prevent an actual incident from occurring (Levels 3 and 4).

At Level 1 of the error trajectory, organizations are required to manage the opportunity for sleep probabilistically. In general, prescriptive rule sets or fatigue modeling are the most common ways in which an organization can determine prospectively whether a pattern of work is likely to provide employees with an adequate opportunity to obtain sufficient sleep (vis-à-vis the defined threshold). Using this approach, an acceptable roster or schedule is one that is associated with a certain percentage of people on average (e.g., > 95%) having an adequate opportunity to gain the requisite amount of sleep.

At Level 2 of the error trajectory, individuals use the PSWM to determine whether they have had sufficient sleep. Since Level 1 control mechanisms will allow a predetermined percentage of employees insufficient sleep (e.g., 5%) the personal PSW calculation will allow them to identify themselves and report this information, and the organization can engage in appropriate control procedures at Level 3 and above in the error trajectory.

In determining appropriate threshold values for sufficient sleep, this review acknowledges that currently there is a dearth of organization- and/or task-specific data sufficient to answer this question definitively. Indeed it is our view that such data will be collected by organizations in the post-implementation phase.

In defining this threshold, readers are cautioned that particular occupational tasks may well be more susceptible to fatigue-related error or the consequences of fatigue-related error are so severe as to require threshold values greater than have been specified. Furthermore, any initial values should be viewed as a starting point and subject to revision in the light of actual workplace experience.

However, where thresholds are inappropriate, one should see the systematic projection of error trajectories beyond Level 2. That is, despite achieving the requisite threshold levels of sleep the FRMS would continue to observe either

- Level 3 factors indicating the occurrence of fatigue-related behaviors or symptoms,
- Level 4 factors related to the occurrence of fatigue-related errors, or
- Level 5 issues related to the occurrence of actual fatigue-related incidents.

Level 3 of the error trajectory is characterized by the presence of fatigue-related behaviors. There will inherently be individual differences in the experience of fatigue as a direct consequence of sleep. That is, even if an individual complies with the organization's minimum sleep thresholds (as set out in Levels 1 and 2), it is possible, due to specific work environment or life circumstances, that the individual may still experience fatigue symptomology. Thus, the observance of fatigue-related behaviors acts as an additional layer of defense, to avoid fatigue-related errors or accidents. The types of controls envisaged at this level would include subjective reports of fatigue from individuals to managers, or the presence of symptoms from a "fatigue symptom checklist," which would be provided to employees by the organization.

While Levels 1-3 of the error trajectory take a proactive approach to fatigue risk management, Levels 4 and 5 take a more reactive approach. They are more concerned with investigative procedures when failures have occurred at the earlier levels of the error trajectory.

Level 4 is defined by the occurrence of a fatigue-related error. Such an error may not necessarily lead to an actual accident or incident. However, if it is detected, an investigation should be conducted to determine the cause of the error and prevent similar occurrences from happening again. Specifically, the investigation should focus on Levels 1-3 to determine deficiencies in the control processes. This would be performed as a part of the safety management system error analysis framework.

Level 5 is the final level in the error trajectory, whereby a fatigue-related error results in an incident or accident. In reality, it is unlikely that such an event would be solely caused by fatigue and could be linked to several different causal factors. However, to determine the extent to which fatigue was specifically involved, the investigation should focus on Levels 1-4 of the error trajectory to determine deficiencies in the control processes. This would be performed as a part of the safety management system accident/incident investigation framework. ◆

Aircraft Size Doesn't Matter

There is much to be gained from small-aircraft accident investigations, from the value of the ultimate recommendations to the lessons learned by the investigators.

By Lorenda Ward, National Transportation Safety Board, USA

(This article was adapted, with permission, from the author's presentation entitled The Size of the Aircraft Doesn't Matter, *presented at the ISASI 2004 seminar held in Australia's Gold Coast region Aug. 30 to Sept. 2, 2004, which carried the theme "Investigate, Communicate, and Educate." The full presentation including cited references index is on the ISASI website at www.isasi.org.—Editor)*

There is much to learn from an accident investigation, no matter how large or small the accident aircraft may be. The truth of that is evident in three accident investigations that the Safety Board conducted involving small aircraft. The value that can be gained from such small investigations, i.e., safety recommendations, and the lessons learned by our investigators during these investigations may be valuable to future investigative efforts. The three investigations involved

- the crash of a Raytheon Beechcraft 1900D in Charlotte, N.C., Jan. 8, 2003, that resulted in 22 safety recommendations to the Federal Aviation Administration (FAA). The recommendations mainly focused on maintenance and weight-and-balance issues and the oversight of those issues.
- a Beech Super King Air carrying the Oklahoma State University basketball team that crashed on Jan. 27, 2001, near Strasburg, Colo., in IFR conditions. The NTSB made an unprecedented recommendation to the National Collegiate Athletic Association, the National Association of Intercollegiate Athletics, and the American Council on Education to improve collegiate air travel policies and procedures.
- another Beech Super King Air accident that occurred in Front Royal, Va., on Oct. 26, 1993, while the aircraft was on an FAA repositioning flight. Seven of the eight recommendations to the FAA dealt with the structure of the FAA flight program. The Safety Board recommended that the FAA model its flight program after a civilian Federal Aviation Regulation (FAR) Part 135 operation.

Lorenda Ward *is an investigator-in-charge (IIC) for the National Transportation Safety Board. She was part of the NTSB team that supported the FBI at both the Pentagon and the World Trade Center after the Sept. 11, 2001, terrorist attacks. She was the IIC for Air Midwest Flight 5481 and the U.S. accredited representative to numerous foreign accident and incident investigations. Before coming to the Safety Board, she worked for the U.S. Navy as an aerospace engineer on the EA-6B and F-14 programs. She has both a bachelor's and master's degree in aerospace engineering from Auburn University and holds a private pilot's license.*

The Beech 1900D accident occurred on Jan. 8, 2003, in Charlotte, N.C.

Charlotte investigation

The Beech 1900D accident occurred on Jan. 8, 2003, in Charlotte, N.C. I served as the investigator-in-charge (IIC) and followed the accident investigation from beginning to end. The final report was issued just a little more than a year after the accident, which occurred shortly after takeoff, killing the two crew members and 19 passengers. The aircraft was destroyed by the ground impact and post-crash fire.

Because this accident occurred just after takeoff, we began by looking at the flight control systems and how the aircraft was loaded: The first question was, "Did the crew members calculate the weight and balance correctly?" We found that they did. Given the weight-and-balance procedures that were in place at the time, the crew members actions were proper.

However, we also found that the use of average passenger and baggage weights (as opposed to actual weights) resulted in a computed weight that differed greatly from the actual weight. In other words, if the weight-and-balance calculation had been based on the true weight of the passengers and baggage, it would have been apparent to the pilots that the flight was well outside the center of gravity (cg) envelope and over maximum takeoff gross weight. The important issue here is that the flight crew was erroneously led to believe that their cg was further forward than it actually was. This resulted in the flight taking off in a significantly tail-heavy condition.

While the weight-and-balance issues were being examined, the systems group was examining the flight control systems. In the airplane wreckage, the pitch control (or elevator) turnbuckles were found at an unusual setting. The maintenance records revealed that maintenance was performed on the accident aircraft's elevator system a few days earlier. The turnbuckles had been adjusted during that time.

Interviews with maintenance personnel revealed that during the maintenance, a mechanic, who was receiving on-the-job training (OJT) at the time, found that the elevator cable tension was low and he adjusted the cable tension using the elevator rigging procedure in the maintenance manual. But, with the approval of his OJT instructor, he *selectively* skipped some of the other steps in the rigging procedure. The result was that the newly rigged elevator now had limited travel in the airplane-nose-down direction. The combination of the limited elevator travel and the aft cg resulted in the airplane losing pitch control, which was what the Safety Board determined to be the probable cause of the accident.

Thus, the investigating team had two major issues to contend with: the use of incorrect average weights and the maintenance training program for mechanics. Almost all of the recommendations issued to the FAA dealt with these issues. A few of the recommendations will be highlighted. A full listing of the safety recommendations appears in the final report (Aircraft Accident Report NTSB/AAR-04/01), which is posted on the Safety Board's website at http://www.ntsb.gov.

Weight-and-balance recommendations—The use of assumed average passenger and baggage weights (in place of actual weights) for weight-and-balance calculations has long been an industry practice for carriers operating aircraft with more than nine passenger seats. However, using average weights has potential problems. The assumed average weights may not be an accurate representation of the general population, and the actual passengers weights on a given flight may not represent the statistical norm of the general population. For example, a survey conducted after the accident found that the actual average weight of American adults was roughly 20 pounds higher than the average weights being used in many operators' average weight programs. Accordingly, the use of average weights carries a risk of being outside the weight-and-balance envelope, which was the case with the accident in Charlotte.

Baggage weights are extremely important for small aircraft. This is because unlike a large aircraft within which baggage can be moved from one cargo hold to another to change the cg, in smaller aircraft, such as the Beech 1900D, there is only one cargo hold.

Clearly, if average passenger weights are not valid then the use of average weights does more harm than good. The Safety Board recommended that the FAA identify situations where actual weights were required versus average weights and further recommended that the FAA examine technology for using actual weights versus average weights. The Safety Board also recommended that the FAA require air carriers to periodically survey passenger and baggage weights, to retain the data from their survey, and to develop cg safety margins to account for variances in average weights of passengers and baggage.

Maintenance program recommendations—As a result of its findings regarding the maintenance of the accident aircraft's elevator cables, the Safety Board recommended that aircraft manufacturers establish appropriate procedures for a complete functional check of critical flight systems after maintenance work has been done on that system and that air carriers incorporate those checks in their maintenance procedures.

This may sound like a common-sense item, but, to our surprise, it wasn't being done, nor was it required. The Board also looked at how maintenance training was being accomplished, especially OJT, and recommended that maintenance training programs be approved by the FAA, just as the training programs for pilots and flight attendants are. Many of the other maintenance-related recommendations focused on the need for improved maintenance oversight by both the operators and the FAA.

Investigation lessons learned—An investigation safety lesson was learned the hard way when a systems investigator slipped and injured his back while working around the wreckage. The investigator was wearing the protective footwear covers (yellow booties) that are included with the PPE kit. These covers are required to be worn in areas where bloodborne pathogens may be present. The investigator slipped because the footwear covers do not have good traction on slippery surfaces. They also have a tendency to get caught on objects or become torn from contact with sharp edges. After this incident, our OSHA representative researched other footwear options that would meet our bloodborne pathogen program requirements and not add to the safety hazards presented by the work environment. The OSHA experts have offered several possible replacement boot types.

Strasburg investigation

Another example of a less-complex investigation that led to important increases in air safety concerned the loss of a Beech Super King Air on Jan. 27, 2001, near Strasburg, Colo. The American public closely followed this accident investigation because the aircraft was carrying members of the Oklahoma State University (OSU) basketball team. Sadly, all 10 people on the airplane were killed.

The immediate cause of the accident was reasonably straightforward. The aircraft lost a.c. electrical power and, thus, primary flight instrumentation during a climb through instrument meteorological conditions. This probably occurred because of a failed electrical relay or inverter. The Safety Board determined that although standby flight instruments should have been available, the pilots became spatially disoriented and lost control of the airplane.

During the investigation, ancillary re-

The Beech Super King Air accident occurred on Jan. 27, 2001, near Strasburg, Colo.

search revealed that Oklahoma State University did not provide any significant oversight of this flight, or any other school-sponsored flight carrying students to events away from the university.

Furthermore, the Board determined that this may have been true at many other colleges and universities around the nation. To its credit though, with the encouragement of the Safety Board, OSU formulated a comprehensive travel management system that now promotes safe university-sponsored travel and provides the necessary oversight to ensure that transportation services are carried out in accordance with the provisions of the revised policy. For example, in addition to the oversight provided by the university's athletic director, athletic staff, and coaches, OSU now retains an aviation consultant with expertise in operations, safety, and certification of aircraft.

Recommendation—The Safety Board thought that OSU's new safety-oriented travel policies were developed well enough to make a formal recommendation to encourage the National Collegiate Athletic Association, the National Association of Intercollegiate Athletics, and the American Council on Education to follow OSU's lead in these matters. Again, although this accident involved a small airplane, the results of the investigation and proactive participation by Oklahoma State University will undoubtedly save lives in the future.

Lessons learned while on scene—This is one of the Board's first on-scene investigations where a new on-scene hazard "risk analysis" form was completed before actually launching and every day while working on the wreckage. The IIC uses this form as a planning tool to make everyone more aware of the hazardous conditions that the investigators are working under. On the form, a numerical value is assigned to a variety of working conditions (weather, lighting, terrain, and the like). If the total value exceeds a certain number, then a mitigation plan has to be put in place.

In this case, an identified risk was the very cold weather at the accident site. The IIC chose to combat the cold conditions by having several vehicles lined up along the debris field with the engines running and the heaters on. These vehicles acted as warming stations for the investigators and were heavily visited.

Front Royal investigation

Yet another Beech Super King Air accident also illustrates the fact that the size of an accident often has little to do with the actual safety benefits of good recommendations. This accident involved an aircraft operated by the FAA that crashed into mountainous terrain during a repositioning flight near Front Royal, Va., in 1993. The Board determined that the probable cause of the accident was the failure of the pilot to stay in visual meteorological conditions (VMC) while in mountainous terrain.

An important aspect of this rather straightforward case concerned discovery during the investigation of the shortcomings within the entire, quite fragmented, FAA flight program. For instance, Board investigators found that although each FAA flying unit had a check airman, training captain, and safety officer slots, these positions were always considered extra duties, and decisions made by these pilots were often overridden by people not directly associated with the FAA flying program. In addition, due to scheduling biases, an unusual supervisory structure, and a lack of available flying time, FAA first officers were that in name only. They were rarely allowed to actually fly and land the airplanes and, for the most part, only served as radio operators on FAA flights.

Recommendations—Seven of the eight recommendations to the FAA that resulted from this investigation had to do with the structure of the FAA flight program, rather than the actions of the flight crew that crashed the airplane. In short, the Board recommended that the FAA flight program model itself after a civilian FAR Part 135 operation, with all the checks and balances, inspection requirements, and aircraft and pilot certifications standards that a small airline would be subject to. The FAA took these recommendations very seriously, and its flight program today is much safer than it was in 1993.

Lesson learned—The accident occurred in daylight conditions, but when one investigator, who lived close to the accident site, arrived on scene, it was dark. The wreckage was in a mountainous area, and the terrain was rugged; but this investigator, anxious to do his job, began searching for the wreckage. When the IIC learned of this, he immediately told the investigator to stop his search effort to prevent him from possibly injuring himself. The following day the wreckage was located by aerial search. The lesson learned here is obvious. Any type of search effort, or any work on aircraft wreckage at all for that matter, is usually not advisable unless such actions can be done under very controlled, safe conditions.

In conclusion, there is much to be gained from small-aircraft accident investigations. As is evident from the three accidents discussed here, more than two dozen recommendations were issued that undoubtedly have saved lives, and quite a few valuable lessons on how to investigate safely were learned. ◆

(This article was adapted, with permission, from the author's presentation entitled WYSIWYG—Or Is It? *presented at the ISASI 2004 seminar held in Australia's Gold Coast region Aug. 30 to Sept. 2, 2004, which carried the theme "Investigate, Communicate, and Educate." The full presentation including cited references index is on the ISASI website at www.isasi.org.—Editor)*

WYSIWYG—Or Is It?

Making a case for the need of a standard for secure digital photography in accident investigation.

By Corey Stephens and Chris Baum, Air Line Pilots Association, International

One has only to stop and look around at any contemporary major accident investigation site to realize that digital devices are in widespread use in the accident investigation community. Among these are an ever-increasing number of digital cameras, in many cases outnumbering film cameras as the tool of choice for recording the entire spectrum of accident scenes, from close-ups of failed components to aerial views of the accident site. Notwithstanding the completely valid school of thought that advocates disposable film cameras over any other type (cheaper, simpler, readily available, zero maintenance, no training required, low probability of error, etc.), digital cameras appear to be here to stay—at least until replaced by the next quantum leap in photographic technology.

Similarly, one has only to review current published government guidance on the conduct of an investigation to realize that no specific accommodations are generally being made to account for the different character of the digital medium vis-à-vis the optical (film) one. In the United States and Canada, there are no specific chain-of-custody requirements to ensure that the computer file representing the digital image is not copied illicitly, altered, or destroyed. Similarly, there is no guidance on use of any particular format for digital imaging, and no format yet exists that would allow investigators or other users of digital photography to positively check the validity of an image and identify any changes made to it (as well as when such changes were made, what they were, and who made them).

Is there a need for such a standard to verify the authenticity of digital photographs? Let' s examine the question and begin with a discussion of how film cameras have been used and misused in investigations of various types over time, and how digital cameras have come to be used in the field of aircraft accident investigation today.

Film photo fakery

Dino A. Brugioni quotes the following material from a review of the book *Photo Fakery: The History and Techniques of Photographic Manipulation*. The review was found posted on FCW.com (Federal Computer World).

"Since the early 19th century, people have come to accept what they see in photographs as reality. The adage that 'the camera never lies' has come to be accepted as historical fact, buttressed by the faith taken daily by all who read a newspaper or magazine that what is depicted in photos actually happened.…

"'The art of producing fake photography predates the computer by almost a century, and some of America's well-known and most beloved figures have not gone unscathed,' according to Brugioni. For example, when photographer Matthew Brady first photographed President John Calhoun, he had no idea that an eager entrepreneur would later take a reversed image of Abraham Lincoln's head and graft it onto Calhoun's body for a new engraving. Not only was Lincoln's head also substituted on the bodies of Alexander Hamilton and Martin Van Buren, but the famous photo of 'The Martyr Lincoln,' which depicts Lincoln in his casket, has since been proven to be fraudulent, Brugioni writes.

"Other well-known doctored photographs

***Corey Stephens** is a staff engineer with the Engineering and Air Safety Department of the Air Line Pilots Association, International (ALPA). His current duties include participating in all of ALPA's accident investigation activity, and he is the staff lead for ALPA's Advanced Accident Investigation Course.*

***Chris Baum** is the manager of ALPA's Engineering and Accident Investigation Section. He supervises all support activities associated with ALPA's accident investigation efforts. He has been with ALPA for 8 years. Prior to coming to ALPA, Baum spent 23 years in the U.S. Air Force in a variety of operational and staff positions.*

include the recently debunked 1934 depiction of the Loch Ness monster that appeared in a London newspaper; a studio portrait of American literary giant Walt Whitman that was used as the frontispiece to *Leaves of Grass*; and an 1865 portrait of Union Army Gen. William Sherman and his staff. More recent examples of tampering illustrated by Brugioni include the controversial darkening of O.J. Simpson's face on the cover of *Time* magazine and the less sinister yet commonplace touchups done to the faces, teeth, and bust lines of today's supermodels.

"According to Brugioni, 'the invention of the Eastman portable camera in 1888, followed by the box camera, opened photography to people in all walks of life.' Now, a little more than 100 years later, the same can be said of the computer. Brugioni's book appears at a time when the technology is readily available for almost anybody with a modicum of computer skills to retouch, change, or forge photos.…

"Likewise, Brugioni uses the mind-boggling pace of technology to paint a bleak picture of the future. 'We can see how photo fakery has made most of us doubters rather than believers,' Brugioni writes. 'With the new and expanding technology, faith in photography as the purveyor of truth has been weakened, and, in the future, it will be further weakened rather than strengthened.'

"Brugioni suggests that in this age of the 'electronic darkroom,' ethics must become 'an important part of a course in digital imaging taught at DOD's Joint Defense Photography School in Pensacola, Fla.' The concern, according to Brugioni, is that the ability to alter photos through electronic manipulation raises moral, legal, and ethical issues for members of the intelligence community who are responsible for providing imagery intelligence to high-level decision-makers in government, including the President.

"Readers are left hanging, however, wondering what, if anything, can be done to avoid a future where nothing can be believed. Brugioni puts forth a strong argument in favor of distrusting the pictures shown in newspapers, in magazines, on television, and on the Internet.…"

It should not come as a surprise to any accident investigator working today that the idea of presenting a photograph to support a textual or other description of some aspect of an investigation is not new. Virtually any modern major aircraft accident investigation will have photographs of wreckage, ground scars, general overview of the accident site, and so on. Such use of photography has become routine and is expected.

None of the published accident investigation manuals of the United States, Canada, and ICAO make any mention of the need to verify the validity of photographs prior to using them to support analysis and develop conclusions as to accident causation.

However, a review of the published accident investigation manuals of the United States, Canada, and ICAO reveal that surprisingly little is written in these texts regarding the use of photographs in the course of an investigation. All the aforementioned works refer to photography, suggesting that its use is expected and condoned, but none of these manuals make any mention of the need to verify the validity of photographs prior to using them to support analysis and develop conclusions as to accident causation. The maturity of all these documents suggests that this omission is not an oversight, but rather a reflection of a presumption on the part of the State that the investigator-in-charge will be able to exercise sufficient control over the investigation that he or she will, through the normal investigative process, have confidence that photographs taken in the field will be controlled sufficiently to prevent fraudulent use of altered photographs.

This is likely a valid assumption in the case of traditional optical photographs. While it would not be impossible to take optical photographs of, for example, a suspect component, and in about the same time as would be required for normal developing, remove the film and surreptitiously alter the photograph, the normal processes for controlling access to evidence would tend to prevent such activity (or at least make it obvious).

Conversely, the expanding use of digital photography in investigations does not have the same inherent characteristics that resist tampering. Accident sites at most recent major investigations are virtually awash in computers and related equipment. Each and every one of these devices is potentially an "electronic darkroom" that can be used, in real time, to retrieve, retain a copy of, and display digital photographs. That fact alone means that the possibility of a digital photograph being altered, through either a deliberate act, carelessness, or honest error, is far greater than in the optical photography case.

Add to this the fact that digital cameras are increasing in popularity, increasing in capability, and decreasing in price and the fact that computer software whose legitimate purpose is to *change* digital photographs is doing the same thing, and it becomes easy to see that a potential problem exists that must be managed.

Digital camera use and benefits

Clearly, photography in general has established its place as a valuable investigative tool. It's difficult to imagine any modern investigation being conducted without photo documentation of the overall site, individual failed components, etc. Digital photography, however, is a subset that is still evolving. Subjectively, it appears that in the early years of the technology, investigators viewed it as simply a new type of camera, and it was too soon to tell if the legacy would be "state of the art" or "flash in the pan."

Early digital cameras were expensive and the image quality was inferior to optical cameras. Nevertheless, as investigators became accustomed to using automation in their daily business, and then in the field, the appeal of a device that allowed immediate review of photographs and the ability to copy and move them easily was compelling. The emerging prevalence, if not the advantages, of digital photography made it evident to investigative agencies that this technology had a place in fieldwork. However, this was not a realization driven by the needs of investigators, but rather one of reaction of marketing blitz for digital cameras.

Basically, digital camera use is essentially the same as it is for its optical cousin. The camera as an investigative tool is used to record pertinent details of fractures, burns, scars, switch positions, and so forth. It is used to help the investigator recall the overall orientation of objects, and to enable study of views that may only be obtainable in a transient manner (such as an overhead view from a helicopter). Beyond that, however, there are significant differences between digital and optical that should be examined and understood if the risks and benefits are to be properly balanced.

Perhaps the most evident benefit of digital photography is that it permits the photographer/investigator to immediately see the photo taken, evaluate the picture, make adjustments, and reshoot if necessary. Some later-model cameras have this capability built into the programming and can automatically take a short series of photos, varying the exposure or other parameters slightly for each shot.

In theory, this should result in photographs that are generally more useful to the investigator. On the other hand, however, this same capability introduces some new variables. Optical processing, in general, results in a relatively consistent product. Digital images, however, may vary considerably based only on the output device (e.g., the camera's own LCD screen vs. a laptop's processed video signal vs. a printer's "version" of the image). Depending on the desired subject of the image, these differences may or may not be significant.

Another feature of digital cameras (generally viewed as an advantage) is the elimination of the need for film. In reality, however, the digital device has essentially the same limitations as the optical device—there is a finite amount of storage for the images and when that is used up, the photographer must take some action.

The difference, of course, is in scale. The capacity of storage media continues to go up and the price continues to go down. At the same time, however, the capability of the camera to use large quantities of storage also continues to skyrocket. This is, on balance, a benefit. The upper limit of quality of digital photography (in terms of the image resolution—megapixels) continues to climb, allowing digital images to be made that are nearly indistinguishable in quality from the optical versions and are generally more than satisfactory for most investigative uses.

The net result of the advances in picture quality (as indicated by pixel density) and storage availability clearly favors digital. The photographer can use media that allow recording of tens, if not hundreds, of pictures on devices that can be stored in a pocket, are more robust than traditional film cartridges, can be emptied of their data contents and reused, can be shared among users almost at will (although it is sometimes necessary to have a reading device), and have virtually no expiration date.

The potential problems?

With so many advantages in capacity, immediacy, and portability, one might be inclined to look at digital photography as an invaluable investigative tool. That may well be, but as with any other beneficial item, costs exist that must be balanced, and drawbacks exist that must be evaluated to see if they should be mitigated before using the technology.

Basically, the problems associated with digital photography are essentially the same as for optical photography in investigations. For example, it is equally important, whether the medium is film or digital, to ensure that photographs taken as evidence that leads to determinations of an accident cause can be preserved for proper use by safety investigators, can be validated, and their authenticity verified, and so on. There are a few new protocols that need to be developed for use of digital photography. Implementing those protocols, however, may be significantly more difficult when using digital media.

Image manipulation is perhaps the greatest threat to the use of digital photography. If one were to set out to falsify optical photographs convincingly, one would likely need to have (or have access to) relatively sophisticated darkroom equipment and would also require the expertise to use it. On the other hand, current software is available for relatively little money that not only enables even a novice to alter digital photographs but that also will frequently perform the task itself! If one wanted to be in the business of altering digital photographs and was willing to make an investment in that process, far more sophisticated software is available.

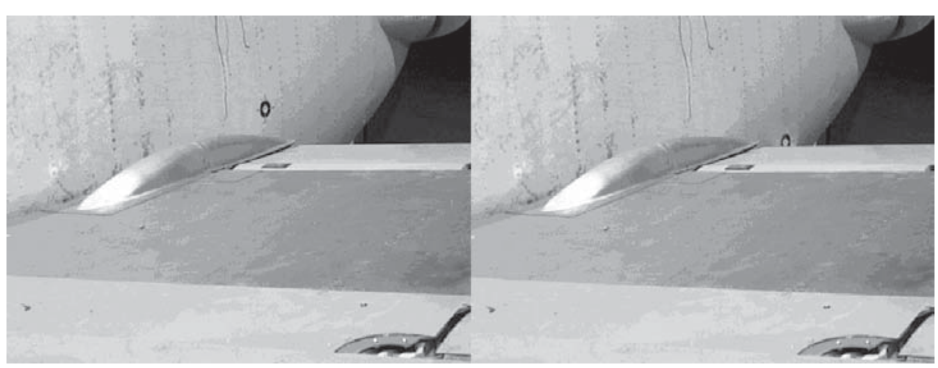
The left photograph shown below illustrates the relationship between the aircraft elevator trailing edge and a manufacturer's alignment mark installed to enable proper elevator rigging. The image on the right was adjusted to change the position of the alignment mark relative to the elevator. The adjustment required software available at any retail computer store and about 15 minutes of effort.

While this is a simplistic example, in an actual investigation there would likely be a number of ways the deception could be uncovered. If the photos were electronically embedded in the document and the document was retained electronically, it might actually be possible to enlarge each photo and clearly see the changes. However, if the photos were printed in a report, such recovery would not be possible. In spite of the simplicity of this example, it illustrates the ease with which a photograph, taken to illustrate a point, can be changed to create an impression quite different from reality.

As with any piece of evidence, a chain of custody is important to ensure that the evidence remains under the control of the investigator-in-charge or other official of the State investigative agency. With physical objects, this is a straightforward process. Even with conventional photographic film, the process that generates a photographic negative can be monitored and the negatives can then be retained for safekeeping.

Such a chain of custody is not as simple or straightforward with digital media. Given that the "photograph" takes the form of a computer file, duplicates of which can be indistinguishable from the original, identification of source material from copies becomes a significant issue. Even the storage device itself may not be identifiable as an original unless measures are taken initially to do so (e.g., initialed by an investigator or placed in a container with a tamper-evident seal).

The file that contains a digital image can be moved both from and to many types of storage. As a result, it is possible to capture an image with a camera, store it to a digital storage medium, move it from that medium to a computer for processing, change it and move it back to the storage medium as a different image. Most computer users realize that files have attributes, and among those attributes is a date and time. This is frequently the information used to distinguish one version of a file from a later, presumably changed, version. This feature may be of value in determining if a



file has a date and time consistent with its "status" as an original investigation artifact.

However, depending on the software used, the file date and time on a computer may be the date and time the file was downloaded off the medium onto a computer for legitimate investigative use, even if the file was unchanged. Thus, the presence of a date and time later than the field phase of the investigation is not explicitly indicative that the file has been changed.

Finally, one must consider the volatility and fragility of a digital image. As a rule, digital storage media are robust and relatively resistant to mechanical damage. They are, however, not impervious to mistakes, mishandling, or other hazards. If a role of conventional photographic film is somehow damaged, portions of the images on the film may be recoverable. If the digital medium is mechanically damaged, it is far less likely that any information is recoverable. In addition, as most computer users know, there is the distinct possibility of human error causing loss of data. The difference between "Erase All—Yes" and "Erase All—No" may be so slight as to allow the user to defeat the manufacturer's safeguards. And as every computer user also knows, once a file is truly gone, it is generally gone forever.

Other users

How are other organizations and agencies handling this? The Federal Bureau of Investigations (FBI) has been looking at these same issues. An examiner in the FBI Laboratory's Special Photographic Unit, Special Agent Douglas A. Goodin described in February 1996 in a paper entitled *Image Security and Integrity,* "The ease with which images can be changed is the central issue in image integrity. The impermanent recording of an image by rearranging a bunch of magnetic particles and corresponding pixels seems to lack the security and integrity of good old film."

Special Agent Goodin believes that at a crime scene when a digital camera is used, a greater problem for law enforcers may surface. "The photographer may have been the only one there at the time. A particularly damning piece of evidence could be later undetectably inserted into the images through an image-processing program. As digital photography becomes more widespread in law enforcement, I could see this becoming a problem for overzealous or dishonest officers."

In a recent case in the United States, the prosecution team in a trial was accused of photo manipulation. During the O.J. Simpson murder trial, prosecutors entered into evidence a picture of Simpson wearing the now infamous Bruno Magli shoes. The defense claimed Simpson didn't wear those shoes and the photograph was manipulated, and thus objected. Expert witnesses were then called in. Two experts gave their analysis of the photos, but each gave a different view. This issue was finally settled when a roll of film that contained pictures of Simpson wearing the Bruno Maglis was discovered and entered into evidence. If not for that roll of film, or had the original image been digital, the original photograph probably wouldn't have held up as evidence.

In June 2002, the Scientific Working Group on Imaging Technologies (SWGIT), of which the FBI is involved, released Version 1.2 of its recommendations and guidelines for the use of digital image processing in the criminal justice system.

The Group's objective is "…to ensure the successful introduction of forensic imagery as evidence in a court of law." Its work includes brief descriptions of advantages, disadvantages, and potential limitations of each major digital imaging process. It sees digital image processing as a necessary and accepted practice in forensic science.

The SWGIT Group feels that any changes to an image made through digital image processing are acceptable in forensic applications provided the following criteria are met:

- The original image is preserved.
- The processing steps are logged when they include techniques other than those used in a traditional photographic darkroom.
- The end result is presented as an enhanced image, which may be reproduced by applying the logged steps to the original image.

SWGIT has continued its work by releasing *Minimum Best Practices for Documenting Image Enhancement-Version 1.1* on March 4, 2004. The purpose of this document is to describe the "best practice" documentation of image enhancement used in the criminal justice system. The objective of SWGIT with these standards is to provide laboratory personnel with instruction regarding the level of documentation that is appropriate when performing enhancement operations on still images, regardless of the tools and devices used to perform the enhancement.

SWGIT is using this documentation of image enhancement techniques to help satisfy the legal requirements for the introduction of forensic images as evidence in a court of law. SWGIT has developed two categories by which images can be enhanced—Category 1 and Category 2.

- Category 1 images include "images utilized to demonstrate what the photographer or recording device witnessed but not analyzed by subject matter experts." This would include general crime scene or investigative images, surveillance images, autopsy images, documentation of items of evidence in a laboratory, and arrest photographs ("mug shots").
- Category 2 images include "images utilized for scientific analysis by subject matter experts." This would include latent prints, questioned documents, impression evidence, Category 1 images to be subjected to analysis, and patterned evidence.

SWGIT suggests that Category 1 images need only rudimentary documentation that would describe what type of enhancement(s) was used. Category 2 images require a more detailed description of the enhancement, so that any changes would be clearly spelled out to an expert. SWGIT has also developed a number of standard operating practices (SOPs) for digital and film-based photography. These SOPs cover issues such as first responder photography, surveillance photography, tactical survey photography, hazmat scene photography, aerial photography, and accident scene photography.

The FBI and other agencies have already done much work, and aircraft accident investigators can benefit from that. ISASI could develop SOPs and "best practices" documentation for the accident investigation community. By using this work as a foundation, we can make digital photography more beneficial and reliable as evidence.

Current file formats

File formats that currently support supplemental information about the recorded image include joint photographic experts group (JPEG), tagged image file format (TIFF), exchangeable image file format (EXIF), and TIFF extensions. The need for a uniform file format standard for image data stored by digital still cameras has increased as these cameras have grown in popularity. A similar need has arisen for uniformity of the attribute information that can be recorded in a file. Space precludes a discussion of JPEG and TIFF file formats, but the EXIF and TIFF attribute information that can currently be recorded is covered on the next page.

EXIF was developed by the Japan Electronic Industry Development Association (JEIDA) to be used in digital still cameras and related systems. Version 1.0 was first published in October 1996. Over time, changes have been made to make improvements to the EXIF format for greater ease of use, while still allowing backward compatibility with products of manufacturers currently implementing EXIF Version 1.x or considering its future implementation.

EXIF Version 2.1 contains the current recommended EXIF standards. The file recording format is based on existing formats. Compressed files are recorded as JPEG (ISO/IEC 10918-1iv). Uncompressed files are recorded in TIFF Rev. 6.0v format. By using existing formats, photos taken using a digital still camera or related system can be read directly by commercial applications (i.e., Adobe PhotoShop) and makes viewing and manipulating of the images possible. Related attribute information for both compressed and uncompressed files is stored in the tag information format defined in TIFF Rev. 6.0. Information specific to the camera system and not defined in TIFF is stored in private (manufacturer) tags registered for EXIF.

The reason for using the TIFF Rev. 6.0 tag format in the compressed file is to facilitate exchange of attribute data between EXIF compressed and uncompressed files. A feature of EXIF image files is their compatibility with standard formats in wide use today, enabling them to be used on personal computers and in other information systems. The intention of JEIDA is to promote widespread use of digital still cameras. Figure 1 below shows what data are recorded under the TIFF Rev. 6.0 attribute information tags. Figures 2 and 3 show the fields that are recorded under EXIF. For a full description of all fields, reference Digital Still Camera Image File Format Standard (Exchangeable image file format for Digital Still Camera: EXIF), Version 2.1, JEIDA-49-1998).

EXIF allows more than just the recording of image specific attributes. EXIF also allows the recording of specific location information acquired by a GPS receiver. This feature can be very beneficial in an accident investigation. Not only is latitude and longitude information captured, but other references such as GPS time (atomic clock) and reference points used to determine direction of movement and direction of image are captured. Figure 4 shows a complete list of GPS attributes that can be recorded under EXIF.

While EXIF and TIFF extensions are very useful, they do have some limitations. If the images are opened in an application that does not support the readout of attributes, and then saved, the information will be lost. If that is the only copy of the image, then all electronically recorded history of that file will be lost. Another limitation is garbage-in garbage-out (GIGO). If the settings in the camera (i.e., time and date) are not correct, then the values will be recorded incorrectly. Also, many camera manufacturers release firmware updates to fix minor "bugs" in the camera's operating system. If there is a firmware problem, it is possible that the correct data will not be recorded. Likewise, the GPS location information will be limited to the accuracy of the data source. If a differential GPS system is not used, then the investigator runs the risk of the photos not matching up with the survey locations.

Tag Name	Field Name	Tag ID		Type	Count
		Dec	Hex		
A. Tags relating to image data structure					
Image width	ImageWidth	256	100	SHORT or LONG	1
Image height	ImageLength	257	101	SHORT or LONG	1
Number of bits per component	BitsPerSample	258	102	SHORT	3
Compression scheme	Compression	259	103	SHORT	1
Pixel composition	PhotometricInterpretation	262	106	SHORT	1
Orientation of image	Orientation	274	112	SHORT	1
Number of components	SamplesPerPixel	277	115	SHORT	1
Image data arrangement	PlanarConfiguration	284	11C	SHORT	1
Subsampling ratio of Y to C	YCbCrSubSampling	530	212	SHORT	2
Y and C positioning	YCbCrPositioning	531	213	SHORT	1
Image resolution in width direction	XResolution	282	11A	RATIONAL	1
Image resolution in height direction	YResolution	283	11B	RATIONAL	1
Unit of X and Y resolution	ResolutionUnit	296	128	SHORT	1
B. Tags relating to recording offset					
Image data location	StripOffsets	273	111	SHORT or LONG	*S
Number of rows per strip	RowsPerStrip	278	116	SHORT or LONG	1
Bytes per compressed strip	StripByteCounts	279	117	SHORT or LONG	*S
Offset to JPEG SOI	JPEGInterchangeFormat	513	201	LONG	1
Bytes of JPEG data	JPEGInterchangeFormatLength	514	202	LONG	1
C. Tags relating to image data characteristics					
Transfer function	TransferFunction	301	12D	SHORT	3 * 256
White point chromaticity	WhitePoint	318	13E	RATIONAL	2
Chromaticities of primaries	PrimaryChromaticities	319	13F	RATIONAL	6
Color space transformation matrix coefficients	YCbCrCoefficients	529	211	RATIONAL	3
Pair of black and white reference values	ReferenceBlackWhite	532	214	RATIONAL	6
D. Other tags					
File change date and time	DateTime	306	132	ASCII	20
Image title	ImageDescription	270	10E	ASCII	Any
Image input equipment manufacturer	Make	271	10F	ASCII	Any
Image input equipment model	Model	272	110	ASCII	Any
Software used	Software	305	131	ASCII	Any
Person who created the image	Artist	315	13B	ASCII	Any
Copyright holder	Copyright	3432	8298	ASCII	Any

Figure 1

Tag Name	Field Name	Tag ID		Type	Count
		Dec	Hex		
A. Tags Relating to Version					
Exif version	ExifVersion	36864	9000	UNDEFINED	4
Supported FlashPix version	FlashPixVersion	40960	A000	UNDEFINED	4
B. Tag Relating to Image Data Characteristics					
Color space information	ColorSpace	40961	A001	SHORT	1
C. Tags Relating to Image Configuration					
Meaning of each component	ComponentsConfiguration	37121	9101	UNDEFINED	4
Image compression mode	CompressedBitsPerPixel	37122	9102	RATIONAL	1
Valid image width	PixelXDimension	40962	A002	SHORT or LONG	1
Valid image height	PixelYDimension	40963	A003	SHORT or LONG	1
D. Tags Relating to User Information					
Manufacturer notes	MakerNote	37500	927C	UNDEFINED	Any
User comments	UserComment	37510	9286	UNDEFINED	Any
E. Tag Relating to Related File Information					
Related audio file	RelatedSoundFile	40964	A004	ASCII	13
F. Tags Relating to Date and Time					
Date and time of original data generation	DateTimeOriginal	36867	9003	ASCII	20
Date and time of digital data generation	DateTimeDigitized	36868	9004	ASCII	20
DateTime subseconds	SubSecTime	37520	9290	ASCII	Any
DateTimeOriginal subseconds	SubSecTimeOriginal	37521	9291	ASCII	Any
DateTimeDigitized subseconds	SubSecTimeDigitized	37522	9292	ASCII	Any
G. Tags Relating to Picture-Taking Conditions					
See Table 5					
H. Tags Relating to Date and Time					
Pointer of Interoperability IFD	Interoperability IFD Pointer	40965	A005	LONG	1

Figure 2

Creating a standard

Now that we have looked at the attributes that are currently recordable for digital photos, let's look at what attributes would be considered essential for accident investigation. These include

- date and time the photo was taken,
- camera settings (exposure, etc.),
- where taken (GPS info),
- the name of the photographer,
- notification of any alterations of the file, and
- a layer of the image that shows the original unaltered image.

Date and time are important and easily recorded. Validity of the data, however, must be ensured as well and is not quite as straightforward. The source of the data can be the camera's internal clock or GPS input. The GPS input would be preferable as it cannot be set incorrectly. If the internal clock is used, then it should be adjusted to the same time format and zone that the investigating agency is using (i.e., local or ZULU).

Camera (equipment type) information is recorded under both the TIFF extensions and EXIF, but camera settings and condition information are only available under EXIF. This type of data includes exposure time, F number, ISO speed rating, shutter speed, flash, exposure program, light source, etc. (For a detailed list, see Figures 2 and 3.)

When the image file is opened in an application that supports EXIF, this data can be viewed, making highly detailed log sheets in the field unnecessary. Information such as the exact location of where a photo was taken and direction are also very important to know. With investigations increasingly using more digitized data from the surveys of accident sites, the ability to bring in latitude and longitude information, as well as the direction the photo was taken, becomes even more valuable. Being able to map out the location of a photo in respect to a specific part or piece of wreckage using precise (differential GPS) measurements is very valuable in post-field activities.

If the camera is set properly, both TIFF extensions and EXIF can record the name of the photographer. This is very important in investigations involving multiple parties or agencies in order to keep the source known. If all that is left at the end of an investigation is a CD full of JPEG files, and no information on the photographer, you cannot be assured of the chain of custody of the images.

There are two other requirements for digital images used in an investigation that are not currently addressed under these formats. The first is the ability to log any alterations or modifications of the file. Any time there is a modification, or a filter is used on an image in an application, there must be a log of those changes. This would allow anyone in the investigation to determine the authenticity of an image. The second is a "layer" of the image that would remain unaltered. This would be similar to Adobe PhotoShop's layering system, except that the base layer would never change. Notations, filters, or other processes could be done on the photo, but the base photo cannot be changed. This allows all parties to recover the original, unaltered image. By using these two features together, the history of a digital image could be viewed by anyone examining the electronic version of an image. However, these safeguards would not prevent an illicitly altered image from being printed and represented as accurate. Ultimately, a process would have to be developed that not only made the electronic image's authenticity verifiable, but would also prevent an altered image from being printed without an indication that it had been altered.

Getting it done

An industry group is needed to address the issues identified above and develop a series of standards. These standards would encompass a format for digital media that allows "audit" of the authenticity as well as a number of processes that would ensure that authenticity of both the electronic and printed form of digital photographs could be verified.

Indeed, the need for this "secure video" capability extends beyond the aircraft accident investigation community. Any discipline that relies on authentic photographs would be affected. All modes of transportation accident investigation, law enforcement, and insurance companies have similar interests, as would a variety of government agencies. Representatives of these groups, along with camera and image processing experts, should be brought together in a cooperative government-industry group to develop standards for "secure" digital photographs.

G. Tags Relating to Picture-Taking Conditions					
Exposure time	ExposureTime	33434	829A	RATIONAL	1
F number	FNumber	33437	829D	RATIONAL	1
Exposure program	ExposureProgram	34850	8822	SHORT	1
Spectral sensitivity	SpectralSensitivity	34852	8824	ASCII	Any
ISO speed rating	ISOSpeedRatings	34855	8827	SHORT	Any
Optoelectric conversion factor	OECF	34856	8828	UNDEFINED	Any
Shutter speed	ShutterSpeedValue	37377	9201	SRATIONAL	1
Aperture	ApertureValue	37378	9202	RATIONAL	1
Brightness	BrightnessValue	37379	9203	SRATIONAL	1
Exposure bias	ExposureBiasValue	37380	9204	SRATIONAL	1
Maximum lens aperture	MaxApertureValue	37381	9205	RATIONAL	1
Subject distance	SubjectDistance	37382	9206	RATIONAL	1
Metering mode	MeteringMode	37383	9207	SHORT	1
Light source	LightSource	37384	9208	SHORT	1
Flash	Flash	37385	9209	SHORT	1
Lens focal length	FocalLength	37386	920A	RATIONAL	1
Flash energy	FlashEnergy	41483	A20B	RATIONAL	1
Spatial frequency response	SpatialFrequencyResponse	41484	A20C	UNDEFINED	Any
Focal plane X resolution	FocalPlaneXResolution	41486	A20E	RATIONAL	1
Focal plane Y resolution	FocalPlaneYResolution	41487	A20F	RATIONAL	1
Focal plane resolution unit	FocalPlaneResolutionUnit	41488	A210	SHORT	1
Subject location	SubjectLocation	41492	A214	SHORT	2
Exposure index	ExposureIndex	41493	A215	RATIONAL	1
Sensing method	SensingMethod	41495	A217	SHORT	1
File source	FileSource	41728	A300	UNDEFINED	1
Scene type	SceneType	41729	A301	UNDEFINED	1
CFA pattern	CFAPattern	41730	A302	UNDEFINED	Any

Figure 3

Tag Name	Field Name	Tag ID		Type	Count
		Dec	Hex		
A. Tags Relating to GPS					
GPS tag version	GPSVersionID	0	0	BYTE	4
North or South Latitude	GPSLatitudeRef	1	1	ASCII	2
Latitude	GPSLatitude	2	2	RATIONAL	3
East or West Longitude	GPSLongitudeRef	3	3	ASCII	2
Longitude	GPSLongitude	4	4	RATIONAL	3
Altitude reference	GPSAltitudeRef	5	5	BYTE	1
Altitude	GPSAltitude	6	6	RATIONAL	1
GPS time (atomic clock)	GPSTimeStamp	7	7	RATIONAL	3
GPS satellites used for measurement	GPSSatellites	8	8	ASCII	Any
GPS receiver status	GPSStatus	9	9	ASCII	2
GPS measurement mode	GPSMeasureMode	10	A	ASCII	2
Measurement precision	GPSDOP	11	B	RATIONAL	1
Speed unit	GPSSpeedRef	12	C	ASCII	2
Speed of GPS receiver	GPSSpeed	13	D	RATIONAL	1
Reference for direction of movement	GPSTrackRef	14	E	ASCII	2
Direction of movement	GPSTrack	15	F	RATIONAL	1
Reference for direction of image	GPSImgDirectionRef	16	10	ASCII	2
Direction of image	GPSImgDirection	17	11	RATIONAL	1
Geodetic survey data used	GPSMapDatum	18	12	ASCII	Any
Reference for latitude of destination	GPSDestLatitudeRef	19	13	ASCII	2
Latitude of destination	GPSDestLatitude	20	14	RATIONAL	3
Reference for longitude of destination	GPSDestLongitudeRef	21	15	ASCII	2
Longitude of destination	GPSDestLongitude	22	16	RATIONAL	3
Reference for bearing of destination	GPSDestBearingRef	23	17	ASCII	2
Bearing of destination	GPSDestBearing	24	18	RATIONAL	1
Reference for distance to destination	GPSDestDistanceRef	25	19	ASCII	2
Distance to destination	GPSDestDistance	26	1A	RATIONAL	1

Figure 4

The resulting standards and processes would ultimately result in a means to take, store, enhance, clarify, edit, copy, and print digital photographs while maintaining the capability to recover the original image and identify all changes made to it.

Establishing standards is never easy—competing interests must be balanced and somebody has to pay for the changes to the status quo. Nevertheless, absence of a means to ensure that photographs taken cannot be altered without irrevocable evidence of that alteration has the potential to result in significant cost to the industry if manufacturing and operations are affected by erroneous conclusions drawn from an investigation based on flawed evidence.

As the capability to take extremely high-quality digital photographs and distribute them instantly around the world expands, as the capability to make changes to digital photographs becomes ever-more sophisticated, and as the potential cost of accidents becomes higher, the need for digital photographs whose authenticity can be positively determined will similarly increase.

The characteristics identified by the SWGIT Group and listed above are straightforward. The original image must be preserved and be recoverable, change must be allowed but must also be logged or tracked, and the enhanced or changed image must be clearly identifiable as such. Defining the changes necessary to hardware, software, and processes would not be difficult. Implementing them in an industry-standard form would be. A standard is needed that can be applied to newly manufactured cameras, retrofit into existing ones, and supported by image editing software. The aircraft accident investigation community has before it an opportunity to take a leadership role in an effort to proactively improve upon a technology to the benefit of all investigations and related activity.

The solution to developing a set of standards for camera, recording media, and related processes is for government and industry to work cooperatively to review the need, identify the requirements, and set the processes in motion that will lead to such standards. ◆

Why Does ACAS/TCAS Fail?

Both airplanes were equipped with ACAS/TCAS II, Version 7 yet collided in midair. A German BFU investigation answers the question 'Why?'

By Johann Reuss, Bundesstelle für Flugunfalluntersuchung (German Federal Bureau of Aircraft Accidents Investigation)

(This article was adapted, with permission, from the author's presentation entitled Airborne Collision Avoidance System: ACAS/TCAS from the Accident Investigation's Point of View, *presented at the ISASI 2004 seminar held in Australia's Gold Coast region Aug. 30 to Sept. 2, 2004, which carried the theme "Investigate, Communicate, and Educate." The full presentation including cited references index is on the ISASI website at www.isasi.org.—Editor)*

On July 1, 2002, a midair collision between a Tupolev TU154M and a Boeing B-757-200 occurred north of the city of Ueberlingen (Lake of Constance). The Tupolev was on a flight from Moscow, Russia, to Barcelona, Spain; the B-757 was on a flight from Bergamo, Italy, to Brussels, Belgium. Both aircraft were flying IFR (instrument flight rules) and were under control of ACC Zurich. After the collision, both aircraft crashed into an area north of Ueberlingen. All 71 persons aboard the two airplanes perished.

The German Federal Bureau of Aircraft Accident Investigation (BFU) investigation team identified the following immediate causes:

- The imminent separation infringement was not noticed by ATC in time. The ATC instruction for the TU154M to descend was given at a time when the prescribed separation to the B-757-200 could not be ensured anymore.
- The TU154M crew followed the ATC instruction to descend and continued to do so even after TCAS advised them to climb. This maneuver was performed contrary to the generated ACAS/TCAS RA.

The following systemic causes were identified:

- The integration of ACAS/TCAS II into the aviation system was insufficient and did not correspond in all points with the system philosophy.
- The regulations concerning ACAS/TCAS published by ICAO and as a result the regulations of national aviation authorities, operations, and procedural instructions of the TCAS manufacturer and the operators were not standardized, were incomplete, and partially contradictory.
- Management and quality assurance of the air navigation service company did not ensure that during the night all open workstations were continuously staffed by controllers.
- Management and quality assurance of the air navigation service company for years tolerated the practice that during times of low traffic flow at night, only one controller worked and the other one rested.

An essential part of the investigation done by the BFU was the investigation of ACAS/TCAS. Although both airplanes were equipped with ACAS/TCAS II, Version 7, the accident was not prevented. One of the major questions in this investigation was why was ACAS/TCAS not able to prevent the midair collision?

ACAS/TCAS operates by interrogating Mode C or Mode S transponders installed in other aircraft, and uses the responses to identify traffic conflicts within a protected volume of airspace around the aircraft. The system generates traffic advisories (TAs) to assist the flight crew in locating and monitoring other traffic that may present a collision hazard. If ACAS/TCAS determines

PHOTOS COURTESY GERMAN BFU

The damaged ACAS/TCAS computer of the TU 154M.

Johann Reuss *has been with BFU since 1987. He has participated in several national and international aircraft accident investigations as an investigator-in-charge, an accredited representative, adviser, or an expert for investigation of avionics equipment. He was chairman of the TCAS Group in the investigation of the accident at Ueberlingen. Reuss is a lecturer for the air crash investigation course at the International University of Applied Sciences Bonn—Bad Honnef.*

that an intruder aircraft will enter the protected airspace around the aircraft, the system generates a resolution advisory (RA). The RA provides the crew with collision-avoidance guidance.

Investigation

To rule out a technical malfunction of the ACAS/TCAS computer, it was a most important aim to read all data stored by the computers.

The ACAS/TCAS computer of the B-757-200 was completely destroyed by impact forces and fire. Some data could be determined by reading the TU154M computer because each airplane's ACAS/TCAS computer involved stored data of the other airplane.

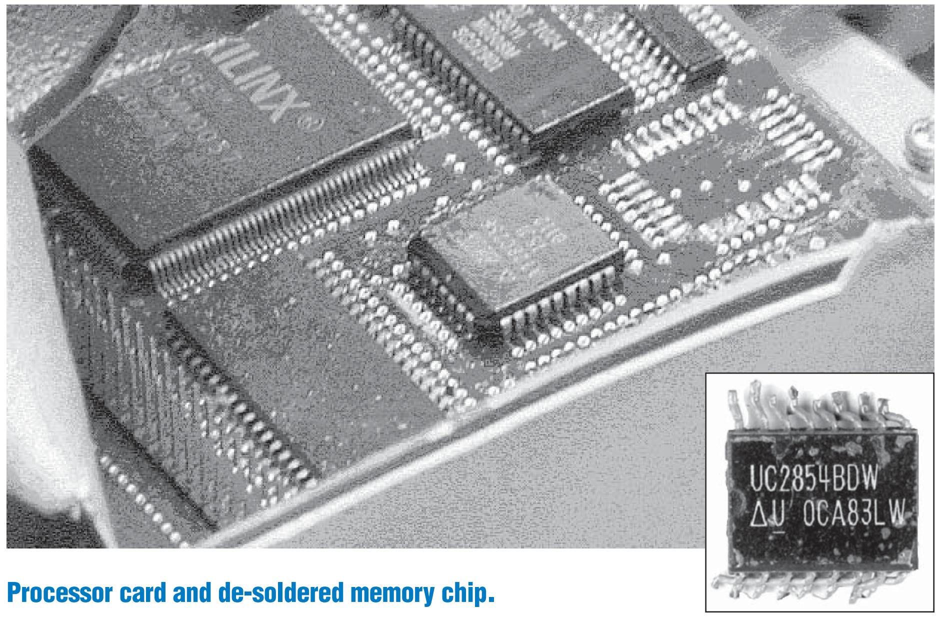
The non-volatile memory of the ACAS/TCAS computer of the TU154M was read at the ACAS/TCAS manufacturer under supervision of members of the BFU investigation team.

The recovered ACAS/TCAS computer of the TU154M had been crushed during impact, and the faceplate was partially detached from the processor chassis. Because of the damage to the computer, the unit was not bench testable. The processor card was not in a condition to be placed into another intact unit in order to download the contents of the memory chips into a serviceable unit. The two identified chips were cleaned and then removed (de-soldered) from the processor circuit card. The chips were placed into a microchip reader and the contents downloaded into a 3.5-inch floppy disk.

The downloaded data were then imported into a software package called TRAFFIQ System (Traffic Resolution Advisories and Fault Failure Inspection and Query System). The event history file was opened and the investigation group examined the resultant data. There were two situations during the flight for which the ACAS/TCAS computer generated event numbers and stored the course of events in the data memory.

The data included the measured values of own aircraft (altitude, bearing, distances) and the altitude information of the intruder received via the transponder. ACAS/TCAS calculated the values for the rate of climb and descent from the received altitude information and stored them. This data could also be analyzed. Therefore, important information for the reconstruction of the flightpaths of both airplanes was available.

The ACAS/TCAS data of the TU154M, shown in table 1, was extractable from the memory.



Processor card and de-soldered memory chip.

Table 1

ime (UTC)	Altitude (feet)	V/S (ft/min)	Intruder Range (nm)	Bearing (deg)	Advisory
21:34:32	35968	217	11.97	325	-
21:34:34	35968	140	11.56	326	-
21:34:36	35968	45	11.16	326	-
21:34:38	35968	49	10.75	328	-
21:34:40	35968	-70	10.31	328	-
21:34:42	35968	-101	9.94	328	TA
21:34:44	35968	-66	9.53	328	TA
21:34:46	35968	-62	9.12	328	TA
21:34:48	35968	-13	8.69	328	TA
21:34:50	35968	42	8.31	328	TA
21:34:52	35968	-65	7.88	329	TA
21:34:54	35968	-166	7.48	328	TA
21:34:56	35968	-155	7.11	326	RA Climb
21:34:58	35968	-168	6.69	325	RA Climb
21:35:00	35968	-451	6.31	323	RA Climb
21:35:02	35968	-705	5.91	322	RA Climb
21:35:04	35840	-1072	5.48	322	RA Climb
21:35:06	35840	-1117	5.09	323	RA Climb
21:35:08	35840	-1421	4.69	323	RA Climb
21:35:10	35712	-1871	4.30	322	RA Climb
21:35:12	35712	-1841	3.91	321	RA Climb
21:35:14	35584	-2025	3.52	321	RA Climb
21:35:16	35456	-2227	3.12	321	RA Climb
21:35:18	35456	-2347	2.73	319	RA Climb
21:35:20	35328	-2377	2.34	316	RA Climb
21:35:22	35328	-2212	1.96	315	RA Climb
21:35:23	35200	-2152	1.77	316	RA Climb
21:35:25	35200	-1920	1.40	315	RA Climb
21:35:27	35072	-1766	1.00	315	RA Climb
21:35:29	35072	-1957	0.63	314	RA Climb
21:35:31	34944	-1841	0.24	307	RA Climb
21:35:33	34944	-1335	0.00	162	RA Climb
21:35:34	34944	-1335	0	152	—

Note: Instead of the relative time scale of the ACAS/TCAS devices (elapsed time), the UTC time was included by the BFU.

Table 2

Time (UTC)	Altitude (feet)	V/S (ft/min)	Advisory
21:34:32	35968	0	—
21:34:34	35968	0	—
21:34:36	35968	0	—
21:34:38	35968	0	—
21:34:40	35968	0	—
21:34:42	35968	0	—
21:34:44	35968	0	—
21:34:46	35968	0	—
21:34:48	35968	0	—
21:34:50	35968	0	—
21:34:52	35968	0	—
21:34:54	35968	0	—
21:34:56	35968	0	RA Descent
21:34:58	35968	0	RA Descent
21:35:00	35968	0	RA Descent
21:35:02	35968	0	RA Descent
21:35:04	35968	-377	RA Descent
21:35:06	35840	-624	RA Descent
21:35:08	35840	-1222	RA Descent
21:35:10	35840	-1462	RA Descent
21:35:12	35712	-1541	RA Descent
21:35:14	35712	-1987	RA Descent
21:35:16	35584	-2047	RA Descent
21:35:18	35456	-2640	RA Descent
21:35:20	35456	-2617	RA Descent
21:35:22	35328	-2700	RA Descent
21:35:23	35328	-2535	RA Descent
21:35:25	35200	-2370	RA Descent
21:35:27	35072	-2452	RA Descent
21:35:29	35072	-2422	RA Descent
21:35:31	34944	-2392	RA Descent
21:35:33	34816	-4260	RA Descent
21:35:34	34688	-4260	—

Note: Instead of the relative time scale of the ACAS/TCAS devices (elapsed time), the UTC time was included by the BFU.

- Altitude: Resolution 128 ft, truncation, calculation based on a source with 25-ft resolution.
- V/S: Calculation based on altitude, resolution 25 ft.
- Intruder Range: Distance from the B-757-200 in nm.
- Intruder Bearing: Angle to the B-757-200 related to the longitudinal axis of the TU154M.
- The advisory "increase climb" was stored in the memory, and the time of storage determined on the basis of the raw data was 21:35:24 hrs.

The following information (Altitude, V/S, and Advisory) is ACAS/TCAS data of the B-757-200 interrogated and stored by the TU154M computer (see Table 2).

- Altitude: Resolution 128 ft, truncation, calculation based on a source with 25-ft resolution. (Transponder reply of B-757-200.)
- V/S: Calculation based on altitude, resolution 25 ft.
- The advisory "increase descent" as an individual command was not transmitted to the TU154M.
- This command was recorded on the CVR at 21:35:10 hrs.

The ACAS/TCAS investigation team also examined the maintenance fault information from the processor card. The following six faults were recorded:

1. XT bus 2 failure
2. Radalt failure: no radalt #2 found
3. CFDS bus fail
4. XT bus 1 fail label error
5. XT bus fail no active XT
6. TA display 1 failure

Design engineers from the ACAS/TCAS manufacturer indicated that there was no current method to correlate the maintenance fault information to the event flight history information.

Operational findings

Based on the recovered data, the following time line shows the functions of the ACAS/TCAS computers after the identification, the positioning, and the transponder interrogation:

21:34:32 hrs

The airplanes flew at FL360 (altitude difference was approximately 50 ft) and at a distance of 11.97 nm.

The ACAS/TCAS of the TU154M localized the B-757-200 at an angle of 325° (-35° related to its own longitudinal axis).

21:34:42 hrs

The ACAS/TCAS devices of both airplanes generated a TA simultaneously. The distance between the two airplanes was 9.94 nm.

21:34:56 hrs

The ACAS/TCAS devices of both airplanes generated an RA simultaneously because they continued to fly at the same altitude. The distance between the two airplanes was 7.11 nm.

The RA in the TU154M was "climb," "climb."

The RA in the B-757-200 was "descend," "descend."

(FDR data showed that both airplanes started to descend at 21:34:57 hrs.)

21:35:10 hrs

The distance between the two airplanes was 4.3 nm.

The ACAS/TCAS of the B-757-200 generated the advisory "increase descent."

21:35:24 hrs

The distance between the two airplanes was 1.54 nm.

The ACAS/TCAS of the TU154M generated the advisory "increase climb."

Both airplanes were still in descent with almost the same rate of descent and an altitude difference of less than 100 ft.

21:35:34 hrs

Collision of the airplanes.

Evaluation of CAS logic

Prior to the issuance of the RAs, the airplanes were in cruise flight with a vertical speed of almost zero and an altitude difference of approximately 50 ft.

Both airplanes reported their altitude in 25-ft increments. They tracked an altitude difference of one or two increments, whereas the B-757-200 was below the TU154M. Thus the altitude difference was the decisive factor for the selection of the direction of the RAs—CAS logic avoids crossing trajectories.

Following the RAs and the initiated avoidance maneuvers, the calculated distance at the CPA (closest point of approach) normally increases until the ACAS/TCAS computer generates the aural annunciation "clear of conflict."

Due to the contrary reaction of the TU154M crew, the calculated distance to the B-757-200 at the CPA did not increase. Fourteen seconds after the initial RA, the CAS logic of the B-757-200 generated an RA "increase descent" (increase the rate of descent from 1,500 ft/min to 2,500 ft/min) in order to resolve the persistent conflict. The CAS logic of the TU154M also generated an RA "increase climb" (increase the rate of climb from 1,500 ft/min to 2,500 ft/min) 28 seconds after the initial RA.

The "increase" advisories are not coordinated between the ACAS/TCAS computers of airplanes involved in the encounter. ICAO Annex 10 states that CAS logic computes an extrapolated trajectory instead of using real tracked values. This leads to dif-

In view of the international importance of ACAS/TCAS, the establishment and publication of standardized procedures by ICAO is an essential requirement.

ferent times for the issuance of strengthening RAs in the airplanes involved.

When the crew of the B-757-200 complied with the advisory "increase descent," the altitude difference between the two airplanes decreased.

ACAS/TCAS II, Version 7 is capable of generating a reversal RA, i.e., a coordinated RA into a direction contrary to the initial RA. The reversal is a way out, if during the avoidance maneuver an inversion of the original geometrical situation of the flightpaths occurred. This situation will arise in particular if the crews respond contrary to the initial RA.

Eurocontrol analysis

A Eurocontrol ACAS/TCAS specialist team has analyzed the accident based on three ACAS/TCAS simulations. Three different data sources and two different analyzing tools for ACAS/TCAS II were used.

It is the BFU's opinion that the following important insights can be drawn from the Eurocontrol study:

- The analysis confirmed that the TAs and RAs in both airplanes were triggered according to the design of the CAS logic.
- The simulation and the analysis of the alert sequence showed that the initial RAs would have ensured a safe vertical separation of both airplanes if both crews had followed the instructions accurately.

Moreover, Eurocontrol conducted a further analysis of how TCAS II would have reacted in this case with the modification CP 112, which had already been developed prior to the accident. According to the results provided, ACAS/TCAS would have generated a reversal RA after the initial RA, which would have led to a sufficient vertical separation of both aircraft if the Boeing B-757-200 crew would have reacted according to the reversal RA.

As ACAS/TCAS II, Version 7 is designed as a semiautomatic system that serves as a "last line of defense" in collision avoidance, clear and unambiguous procedural instructions for the crews are an essential prerequisite. This prerequisite is so important because the system philosophy of ACAS/TCAS II, Version 7 provides only one procedure after the issuance of an RA and that is to follow the generated RA.

The decision to follow an RA without reservation could mean that up to the resolution of the conflict the crew has to divert from other obligatory standards, for instance, from instructions for vertical separation issued by ATC and from other general right-of-way rules.

ICAO regulation

In view of the international importance of ACAS/TCAS, the establishment and publication of standardized procedures by ICAO is an essential requirement.

ACAS/TCAS has been mandatory in the USA since 1993 and in Europe and the Middle East since 2000, but is not yet required in other parts of the world. Thus, the installation of ACAS/TCAS was one prerequisite the operator of the TU154M had to meet to be allowed to fly to European destinations. For domestic flights within the Russian Federation, ACAS/TCAS is not presently required.

BFU evaluated the publications of the ICAO concerning ACAS/TCAS as follows:

Annex 2: In Annex 2 (Rules of the Air) procedural instructions for the utilization of ACAS/TCAS are not taken into account sufficiently.

Though the wording, *"The aircraft that has the right of way shall maintain its heading and speed, but nothing in these rules shall relieve the pilot-in-command of an aircraft from the responsibility of taking such action, including collision-avoidance maneuvers based on resolution advisories provided by ACAS equipment, as will best avert collision."* (Rules of the Air, Chapter 3. 3.2.2, Right–of–way) allowed a deviation from the right-of-way rules in the case of a ACAS/TCAS RA. It did not make clear, however, the required consequent action to be taken by the pilot in case of an RA.

Annex 10: The note, *"Contrary pilot response"* […] was adequate and clear; however, its placement in Annex 10 was unfavorable as this Annex contains mainly technical specifications. A better place for this instruction would have been Annex 2 or Doc. 8168.

Doc. 8168, PANS-OPS: In Doc. 8168 the "Operation of ACAS Equipment" was to be described. These objectives have not been achieved, as the descriptions of the procedures were insufficient and unclear. With the statements, *"assists pilots in operation of the aircraft"* and *"Nothing in the procedures shall prevent pilots-in-command from exercising their best judgment and full authority in the choice of the course of action to resolve a traffic conflict."* (3.1.1. and 3.1.2 of Doc. 8168) The pilots were given freedom of decision, which according to the ACAS/TCAS philosophy must not be granted. The procedural requirement to comply with an RA and to immediately report the avoidance maneuver advised by ACAS/TCAS to the controller responsible for the vertical separation was not described clearly enough in the Doc. 8168. Thus, the situation of a coincidence of an RA with an instruction given by the controller had not been dealt with either.

Doc. 4444, PANS-ATM: With the publication of the Doc. 4444 a procedural description (15.6.3.2) has been issued for the Air Navigation Services directing that the controller should not influence the flightpath in cases where the pilot reports a ACAS/TCAS RA, until the conflict has been resolved.

A prerequisite for the effectiveness of this procedural instruction is the timely report of an ACAS/TCAS RA via radio, as an automatic transmission from the aircraft to the ground is not provided.

State Letter AN 11/19-02/82: In the state letter dated Aug. 8, 1997, the procedures to react to an RA and the necessary training procedures were described much more clearly. The wording, however, did not comply with the procedural descriptions in An-

The TCAS 2000 pilots guide does not state clearly enough that the safe separation accomplished through ATC and the tasks of ACAS/TCAS are two different functions.

nex 2 and Doc. 8168; partially, the interpretation was even contradictory.

Specifications/Procedures unclear

The specifications of the ACAS/TCAS manufacturer's pilots guide regarding the ACAS/TCAS system philosophy and the necessary procedures that ensure a safe function were not described distinctly enough. The wording "TCAS 2000 is a backup to the ATC (air traffic control) system and the see-and-avoid concept" could be interpreted that ATC takes priority over TCAS and that TCAS is designated to be implemental or a substitute. It was not clear in the description of the system philosophy that ACAS/TCAS is exclusively meant as a "last line of defense" for the avoidance of a collision and that in this stage ACAS/TCAS advisories must take precedence over instructions given by ATC controllers.

The TCAS 2000 pilots guide does not state clearly enough that the safe separation accomplished through ATC and the tasks of ACAS/TCAS are two different functions. It is not clear that ACAS/TCAS is not part of the conceptual design of ATC.

In the chapter "Pilot Responsibilities," a sufficient directness is missing. On one hand it talks about "backup for ATC," and on the other it uses the following wording:

- Must not delay in responding to the RA.
- Must not modify a response to an RA.
- Must follow the RA maneuver, unless invoking "Emergency Pilot Authority."

The descriptions in the TCAS 2000 pilots guide were the basis of ACAS/TCAS trainings within the operator companies and for the procedures.

Other regulations

TU154M flight operations manual—This passage made clear that ATC has the highest priority in the avoidance of collision risks: *For the avoidance of inflight collisions is the visual control of the situation in the airspace by the crew and the correct execution of all instructions issued by ATC to be regarded as the most important tool. TCAS is an additional instrument that ensures the timely determination of oncoming traffic, the classification of the risk, and, if necessary, planning of an advice for a vertical avoidance maneuver.*

Eurocontrol—All Eurocontrol publications for ACAS/TCAS introduction, training, and utilization have a recommending character. All Eurocontrol documents express a clear ACAS/TCAS philosophy and clear rules of action and procedural instructions following the issuance of an RA.

JAA—The JAA Leaflet No. 11 had no legal significance in the accident, as the States of registry and the States of the operators of both airplanes were not JAA member States.

Aeronautical Information Publication (AIP) Germany—The explanations in the Aeronautical Information Publication Germany concerning ACAS/TCAS were not up-to-date for ACAS/TCAS II, Version 7. With regard to contents several terms, e.g., "Evaluation of ACAS/TCAS," were related to the introduction phase. The procedural instruction for the actions to be taken by the pilots in case of an RA was not worded clearly enough.

Luftverkehrsordnung (LuftVO—Air Traffic Order)—Pursuant to §13 Subpara 9 a deviation from the right-of-way rules was possible. With the wording, *"This also applies to diversionary maneuvers that are based on recommendations given by collision-avoidance equipment on board,"* the pilots are granted a freedom of decision that is not compatible with the system philosophy of ACAS/TCAS II, Version 7. For the purpose of the ACAS/TCAS philosophy, the use of the term "recommendation" is inadequate. In case of an RA, there can be only one reaction of the pilots: to follow the RA.

Furthermore the wording allows two different kinds of interpretation:

The paragraph can mean that independent of the right-of-way rules, an RA must be followed in order to avoid a collision. The paragraph can also mean that the pilots have the option to deviate from the right-of-way rules and the ACAS/TCAS RAs in order to avoid a collision.

In theory it might be possible, in reality not really practicable. In principle it is correct to give the pilot the final power of decision; the pilot, however, has no better basis for his decision than ACAS/TCAS can give.

Advisory circular (AC) by the Federal Aviation Administration (FAA):

In the AC, which had no legal effect on the airplanes involved, the procedures following the issuance of an TA/RA as well as the responsibilities (for the individual flightcrew members) and the training measures were described clearly and unambiguously. The training program of the B-757-200 operator was based on this document.

Safety-related conclusions

- In case of failure by ATC to provide safe separation between aircraft, ACAS/TCAS provides an independent safety net in preventing mid-air collisions.
- ACAS/TCAS is an effective system, but its ability to fulfill its role is entirely dependent on correct and timely flight crew responses to collision-avoidance maneuvers calculated and displayed by the system.
- The procedure for pilots has to include the following elements:

—In the event of an ACAS/TCAS RA to alter the flightpath, pilots shall respond immediately and maneuver as indicated, unless doing so would jeopardize the safety of the airplane.

—Never maneuver in the opposite sense to an RA, nor maintain a vertical rate in the opposite sense to an RA.

- The regulations concerning ACAS/TCAS published by ICAO and as a result the regulations of national aviation authorities, operational, and procedural instructions of the ACAS/TCAS manufacturer have to be standardized, clear, and unambiguous.

Note: Further investigation aspects concerning ACAS/TCAS in the BFU final report are human factors (HF) and training. A download of the final report is available at http://www.bfu-web.de/. ◆

ISASI 2005 Registration Opens

ISASI's 2005 planners of the Society's Dallas-Ft. Worth Chapter, which is hosting the 36th annual international seminar, has developed a detailed website to provide information relative to the Society's premier member event: www.isasi2005.com.

With its theme of "Investigating New Frontiers in Safety," the seminar will span September 12-16 and be held in Ft Worth, Tex., at the Renaissance Worthington Hotel (Marriott), which is providing a special rate of $140 per night to attendees. The rates are good for September 8-18.

While hotel reservations may be made on line, by fax, or by phone, seminar registration requires the completion of a registration form which can be downloaded from the website; it is also available in this issue of *Forum* (see page 27). After the form is completed, it must be mailed or faxed to the appropriate address, depending on the method of registration payment.

The seminar program registration fee is as follows: member $495; student member $225; nonmember $545. If registration is made after August 15, the fees are $545, $250, and $595, respectively. The fee for either of the two tutorials set for September 12 (emergency response preparedness including family assistance issues and helicopter accident investigation) is $95 by August 15 and $125 thereafter. The companion fee is $350 by August 15 and $395 after that date. The fee for the day-long post-seminar function event conducted on September 16 is $95.

Seminar sponsorships are still available in the following categories Blue $1,000, Silver $3,000, Gold $6,000, and Platinum $10,000. Organizations wishing to become sponsors may contact Curt Lewis, seminar chairman, at curt@curt-lewis.com. ISASI is an IRS 501(c)(3)(US) qualified entry. Full details regarding sponsorship opportunities are also available on the seminar website.

At press time, neither the technical speakers schedule nor the program schedule, including the companions program, had been finalized. However, program planners said all schedules will be posted on the seminar's website as quickly as possible. Other information on the seminar website includes full details regarding exhibitor opportunities, hotel accommodations, visitor information, and transportation availability. International air service connects through the Dallas-Fort Worth International Airport, which is served by 25 air carriers conducting 2,300 daily flight operations at the airport. ◆

SCSI Adds Benefit to Memorial Scholarship

ISASI corporate member Southern California Safety Institute (SCSI) has announced that it is marking as "permanent" its up-to-now ad hoc award of a tuition-free scholarship to the annual selectee(s) of ISASI's Rudolph Kapustin Memorial Scholarship Award, said Dr. Peter Gardiner.

He noted that at the 2003 seminar in Washington, SCSI made available to the winners of the scholarship tuition-free attendance to SCSI's aircraft accident investigation course. "Michiel Shuurman, one of the winners that year, took us up on it and he proved to be very successful. We had intended to make this option more permanent, but we were not in attendance in Australia to do so," Dr. Gardiner said.

"The winner(s) can select any regularly scheduled commercial AAI course or, if they have previously completed a basic investigation course, any one of the other SCSI scheduled investigation courses. Unfortunately, SCSI cannot fund their travel or accommodations as part of the scholarship," noted Gary R. Morphew (MO2538), SCSI director of aircraft accident investigation.

ISASI's scholarship committee will formerly present the SCSI proposal to the International Council at its upcoming meeting in May, said Ron Schleede, co-chair of the Society's Scholarship Committee. ◆

Int'l Members Alerted to Upcoming Meetings

ISASI members who are not members of an ISASI regional society or an ISASI chapter are ISASI international members, said ISASI International Councillor Caj Frostell, in announcing that the group will meet at the ISASI seminar 2005 in Ft. Worth, Tex. "We will hold an interna-

2004 Annual Seminar Proceedings Now Available

Active members in good standing and corporate members may acquire, on a no-fee basis, a copy of the *Proceedings of the 35th International Seminar*, held in the Gold Coast, Queensland, Australia, Aug. 30-Sept. 2, 2004, by downloading the information from the appropriate section of the ISASI website at http://www.isasi.org. The seminar papers can be found in the "Members" section. Alternatively, active members may purchase the *Proceedings* on a CD-ROM for the nominal fee of $15, which covers postage and handling. Non-ISASI members may acquire the CD-ROM for a US$75 fee.

A limited number of paper copies of *Proceedings 2004* are available at a cost of US$150. Checks should accompany the request and be made payable to ISASI. Mail to ISASI, 107 E. Holly Ave., Suite 11, Sterling, VA USA 20164-5405.

tional members meeting—probably in parallel with the meetings of the regional societies and the chapters. We will discuss what ISASI can do for the international members and we will discuss the experiences so far with the ISASI Reachout workshops. The Reachout program is in many aspects geared toward the international members," said Frostell.

Another initiative to coincide with the ISASI 2005 seminar is the reactivation of GASIG (Government Investigators Group), Frostell noted. A meeting will be scheduled in connection with seminar, and the venue will be announced at the seminar.

Frostell said that he will be participating in a 2-week accident investigation course in Prague, Czech Republic, in late April, in the ISASI SMS Reachout Workshop in Taiwan from May 10-11, and in the ISASI SMS Reachout Workshop (organized in cooperation with COSCAP-North Asia) in Seoul, Republic of Korea, from May 16-19. ◆

Cranfield SAIC Joins ISASI Corporate Group

Cranfield Safety and Accident Investigation Centre has become a corporate member of ISASI as part of its continued commitment to education and research in accident investigation. Investigation courses have run at Cranfield since 1977 under the direction of past Jerry Lederer Award winner Frank Taylor until his retirement in 2001. Dr. Graham Braithwaite was appointed director in 2003 and since then Cranfield has also worked with rail and marine accident investigators in parallel with its aviation safety and accident investigation activities.

Cranfield's flagship course is a 6-week aircraft accident investigation course, which includes a 3-week fundamentals module that also benefits from speakers and delegates from the rail and marine industries, followed by a 3-week module in advanced aircraft accident investigation techniques. The next AAI course open for enrollment is September 5-October 14, 2005. The Centre's aircraft accident investigation for aircrew and operations executives course is scheduled for October 31-November 11, 2005.

Dr. Braithwaite notes that "the magic of the Cranfield formula has always been the close collaboration with the UK AAIB and other industry partners." He noted that during the 6-week course, delegates will hear from more than 80 different experts and experience a range of simula-tions including a week-long accident investigation on the university's own airport.

In 2004, Cranfield launched a part-time MSc program in safety and accident investigation for the aviation industry, allowing those completing the 6-week course to complete additional modules in areas ranging from human factors and courtroom skills to crashworthiness and forensic science. More details about these course are available at www.cranfield.ac.uk/soe/airtransport/csaic.htm. ◆

Who is Where?

- **Caj Frostell,** ICAO, chief of the Accident Investigation and Prevention (AIG) Section, retired in late 2004. He remains active in ISASI as its International Concillor. He and his wife Raila will continue to reside in Montreal, Canada (although they also maintain residences in Helsinki, Finland, and Eskilstuna, Sweden). Marcus Costa, a former chief of CENIPA in Brazil, is successor to the AIG post. Costa will participate in the ISASI seminar in Ft. Forth in September and is looking forward to working with ISASI.
- **Ken Smart,** United Kingdom chief inspector of air accidents and head of the Department of Transport's Air Accidents Investigation Branch (AAIB), has retired from that service. He remains active in ISASI as president of the European Society.
- **Kay Yong,** Taipei Aviation Safety Council (ASC) chairman and managing director, resigned his post effective April 1. He is the first managing director of ASC, which was established in May 1998. He has served as chairman of the Council since May 2004.
- **Ellen G. Engleman Conner's** term as chairman of the U.S. National Transportation Safety Board has expired, but she is expected to be renominated for the chairman's position.
- **Carol J. Carmody**, U.S. NTSB member, has left the Board after nearly 5 years as a member. She joined the Board on June 5, 2000, as the 30th member of the NTSB, and served 2 years as vice-

Investigating New Frontiers in Safety

September 12-16, 2005
Fort Worth, Texas USA

A professional training seminar for anyone interested in aviation safety presented by

The International Society of Air Safety Investigators

Name:		ISASI No.:
Organization:		ISASI Corp. No:
Address:		
Tel (home:)	Tel (bus):	Tel (mob):
Fax:	Email:	
Name & title for badge:		
Companion's name on badge:		

For room reservatons call the Renaissance Worthington Hotel Fort Worth (Marriott) at 1-817-882-1600 US/Toll-Free: 1-800-468-3571. Conference rate $140/night; use Group Code SASSASA.

Please check appropriate box: ***Please note that all fees are shown in US Dollars.***

	Registration PRIOR TO 16 August 2005	Registration AFTER 15 August 2005
Full Seminar & Functions (per person)		
Member:	[ ] $495	[ ] $545
ISASI Student Member:	[ ] $225	[ ] $250
Non-member:	[ ] $545	[ ] $595
Single day with no functions (per person) (Tue/Wed/Thur):	[ ] $175	[ ] $225
Tutorials (per person)		
Emergency Response Preparedness including Family Assistance Issues	[ ] $95	[ ] $125
Helicopter accident investigation	[ ] $95	[ ] $125
Companion Program (per person)	[ ] $350	[ ] $395
Tuesday Night Party at Billy Bob's of Texas (per person) (See note below)	[ ] $35	[ ] $45

Note: The Tuesday evening, September 13. Billy Bob's Party is included in all Full-Seminar Registrations and the Companion Program.

Post Seminar Function (price per person)	[ ] $95	[ ] $95
Subtotal:		Total Amount Due:

Special Meal Request (Vegetarian, Halal, Vegan, Kosher, etc.):

Credit Card Type (check one) [ ] Visa [ ] Mastercard	Credit Card Number	Expiry:

Name as it appears on the card:

Signature:

Additional Information go to **http://ISASI2005.com/**
or contact:
(US) Curt Lewis,
Tel 1.817.845.3983 Email curt@curt-lewis.com

(US) John Darbo,
Tel 1.817.685.7410 Email johndarbo@aol.com

If paying by Money Order or Check, please make them payable to "ISASI DFW Chapter" and send by post to:
Curt L. Lewis, P.E., CSP
Post Office Box 120243
Arlington, TX 76012 USA

If paying by Credit Card, **FAX** to:
(703) 430-4970

Cancellations made before 15 July 2005 (Dallas) will incur a $10 processing fee. Cancellations made between 15 July 2005 and 15 Aug
incur a $75 administration fee. There will be no refunds for cancellations after 15 August 2005. Registrations are transferable.

New Members

Corporate
AeroVeritas Aviation Safety Consulting Ltd., CP0233
Mark J. Mohelnitzky
Alexandra Mohelnitzky
Aircraft Mechanics Fraternal Association, CP0230
John T. Glynn
Kiss A. Ernie
Centurion, Inc., CP0232
Anthony B. Gudgeon
Daniel A. Kleynhans
Cirrus Design, CP0231
William T. King
Robert M. Busch

Individual
Alsawagh, Mukhled, KH, MO5129, Kuwait, Kuwait
Carrelli, Michael, A., MO5126, Maungaraki, New Zealand
Cumbie, Robert Mike, MO5142, Woodbridge, VA, USA
Dellanave, Juan, G., MO5137, Montevideo, Uruguay
Ferrero, Leonardo, B., ST5135, Trieste, Italy
Fitzsimons, Lisa, AO5145, Bristol, United Kingdom
Geil, Timothy, G., MO5130, Allen, TX, USA
Gimas, Simeon, AO5128, Larisa, Hellas
Gretz, Robert, J., MO5127, Pompton Lakes, NJ, USA
Hunt, Bryan, W., ST5131, Daytona Beach, FL, USA
Jacobson, Phillip, D., FO5132, North Richland Hills, TX, USA
Jones, Glenn, W., FO5144, Toowoomba, Qld, Australia
Kashambo, Barry, A., MO5139, Kampala, Uganda
Krajca, Brian, H., FO5134, Euless, TX, USA
Long, Terry, M., MO5141, Orangeville, ONT, CANADA
Madarmeh, Mowaffaq, A., MO5136, Amman, Jordan
Maier, Steven, P., MO5124, Broomfield, CO, USA
Markey, Allison, R., ST5125, Daytona Beach Shores, FL, USA
Okunor, Rex Sunday, MO5143, Egbeda, Lagos, Nigeria
Reil, Carly, D., ST5133, Daytona Beach, FL, USA
Spiegel, Peter, MO5138, Surrey Downs, Australia
Steller, Caren, M., ST5140, Daytona Beach, FL, USA

chairman of the Board from 2001 to 2003.

• **Roger Whitefield** has been appointed for 5 years to the UK Civil Aviation Authority Transport as a part-time non-executive member of the Board of the Civil Aviation Authority (CAA). He will be a member of the CAA's Safety Regulation Group Policy Committee and will have a particular interest in safety regulation. He was head of safety at British Airways until 2004. ◆

IFALPA Begins Accrediting Accident Investigators

The International Federation of Air Line Pilots Associations (IFALPA) has developed a program involving the accreditation of pilot investigators. The purpose of this accreditation is to give the States the greatest possible assurance that the appointed pilot representative will provide the most professional contribution to any investigation. Minimum requirements for accreditation include attendance at an IFALPA-approved accident investigation course.

IFALPA firmly believes that member associations should be entitled to participate in the investigation of commercial aircraft accidents or incidents whenever they occur within their own State, or when they occur in another State and involve pilots and/or commercial aircraft of that State. Such participation should be exercised through the appointment to the investigative body of pilots possessing the necessary training, qualifications, and experience to participate in an investigation as advisors to the investigator-in-charge, or the State accredited representative

IFALPA has developed detailed policy in relation to aircraft accident/incident investigation and has initiated its own structure. The Federation believes that the participation of active commercial pilots fully qualified as investigators on official investigative boards will always be of paramount importance.

An IFALPA-sanctioned accident investigation course was recently run for the first time in ASPA de Mexico's headquarters in Mexico City. Some 25 delegates, mostly from the South American member associations, attended the course, organized by the University of Southern California (USC). Arnaud du Bedat, IFALPA's technical officer responsible for the accident analysis committee, also attended. The course was run by former U.S. NTSB accident investigators and included instruction on investigation methods, technical issues, medical matters, and aircraft systems. ◆

FAA Moves to Upgrade Black Boxes

The FAA proposes significant upgrades to aircraft "black boxes" to increase the quality, quantity, and survivability of recorded data, said the agency.

Under the proposed rules, all voice recorders must record the last 2 hours of cockpit audio instead of the now required 15 to 30 minutes. Also, required is a 10-minute independent backup power source for the voice recorders to allow recording even if all aircraft power sources fail. Voice recorders also would have to use technology other than magnetic tape, which is vulnerable to damage and decreased reliability. The proposed rule also clarifies operating requirements for voice recorders, which would have to operate continuously from when pilots begin their checklist before starting the engines until completion of the final

Murphy's Law

By Steven R. Lund

Murphy's Law was conceived at Edwards Air Force Base Flight Test Center in 1949. Named after Capt. Edward A. Murphy, a conscientious engineer working on an Air Force project designed to see how much sudden deceleration a person can stand in a crash.

One day, after finding that an instrument was wired incorrectly, he cursed the technician responsible and snarled, "If there is any way to do it wrong, he'll find it." The scrupulous contractor's project manager kept a list of "laws" and blended Murphy's words with an older phrase, rendering what he labeled "Murphy's Law—If anything ***CAN*** go wrong it ***WILL!***"

Soon, the "law" achieved "guiding principle" status within the workforce and steady effort to circumvent the "law" was credited with the project's successful safety record.

Aerospace manufacturers began using Murphy's Law widely in their advertising, and soon it was being quoted in many news and magazine articles—establishing Murphy's Law and mishap prevention as synonymous.

Along with the other myriad of design safety considerations, the astute designers of military aircraft are keenly aware of Murphy's Law—especially when inventing protection from that *golden bullet* finding its way through any infinitesimal chinks in the cleverly devised armor around vital flight control systems such as the autopilot's digital computers. The designers try to shield those vulnerable human pilots who are allergic to bullets as well.

Perhaps the U.S. has the FAA and Capt. Murphy to thank for the safest commercial airline fleet in the world, by compelling designers to account for all but those extremely remote things that can go wrong.

Safety-conscious commercial airline transport designers are just as mindful of Capt. Murphy, but on a much more sophisticated level. Designers of commercial airliners don't have to concern themselves as much with that one golden bullet; however, they have to consider virtually everything else: from salt-water corrosion to trespassing seagulls.

Airliners must be designed to continue to fly safely considering all but the most improbable of circumstances. Only those things that can be proven to happen in less than one in a billion flights can be excluded from their clever, discerning design considerations. The Federal Aviation Administration defines these rare events as "extremely remote," those that happen with a probability of 1×10^{-9}.

Once they have succeeded in protecting those highly stressed metallic parts from corrosion and then have made the engines and wind-screens less vulnerable to impact damage from those unfortunate, wayward seagulls, they can then proceed with accounting for the many other things that can happen more than once in a billion flights.

Perhaps the U.S. has the FAA and Capt. Murphy to thank for the safest commercial airline fleet in the world, by compelling designers to account for all but those extremely remote things that can go wrong. ◆

checklist when the flight ends. For details of the proposed rule see www.faa.gov/avr/arm/nprm.cfm?nav=nprm. ◆

NTSB Reports Decrease in Aviation Accidents In 2004

The National Transportation Safety Board released preliminary aviation accident statistics in the U.S. for 2004 showing a decrease in several civil aviation categories, including scheduled airliners, air taxis, and general aviation operations.

The total number of U.S. civil aviation accidents decreased from 1,864 in 2003 to 1,715 in 2004. Total fatalities also showed a decrease from 695 to 635. The majority of these fatalities occurred in general aviation and air taxi operations.

General aviation accidents decreased from 1,741 in 2003 to 1,614 in 2004. There were 312 fatal general aviation accidents, down from 352 the year before. The accident rate decreased from 6.77 per 100,000 flight hours in 2003 to 6.22 in 2004. The fatal accident rate decreased from 1.37 to 1.20.

Last year, one fatal accident occurred involving Part 121 airline service. A Jetstream 32 twin-engine airplane operated by Corporate Airlines, doing business as American Connection, crashed on instrument approach to Kirksville Regional Airport, Kirksville, Mo. The accident resulted in 13 fatalities.

Air taxi operations reported 68 accidents in 2004, a decrease from 75 in 2003. The accident rate also decreased from 2.56 per 100,000 flight hours in 2003 to 2.21 in 2004. However, fatalities increased from 42 in 2003 to 65 in 2004. ◆

V.P.'s Corner *(from page 4)*

Brazil—CENIPA www.dac.gov.br/principalIng
Canada—Transportation Safety Board www.tsb.gc.ca
Czech Republic—Air Accident Investigation Institute www.uzpln.cz
Denmark—Accident Investigation Board www.hcl.dk
Finland—Accident Investigation Board www.onnettomuustutkinta.fi
France—Bureau of Investigations and Analysis (BEA) www.bea-fr.org
Germany—Federal Bureau of Aircraft Accidents Investigation www.bfu-web.de
Hong Kong—Civil Aviation Department www.info.gov.hk/cad/english
Iceland—Aircraft Accident Investigation Board http://www.rnf.is
Ireland—Air Accident Investigation Unit www.aaiu.ie
Italy—National Agency for the Emergency of the Flight (ANSV) www.ansv.it
Japan—Aircraft and Railway Accident Investigation Commission www.mlit.go.jp/araic
Korea—Aircraft-Accident Investigation Board www.kaib.go.kr
Netherlands—Dutch Transport Safety Board www.rvtv.nl
New Zealand—Transport Accident Investigation Commission www.taic.org.nz
Norway—Accident Investigation Board www.aibn.no
Singapore—Aircraft Accident Investigation Board www.mot.gov.sg
Sweden—Accident Investigation Board www.havkom.se
Switzerland—Aircraft Accident Investigation Bureau www.bfu.admin.ch
Taiwan—Aviation Safety Council www.asc.gov.tw
United Kingdom—Air Accidents Investigation Branch www.aaib.dft.gov.uk
United States—National Transportation Safety Board www.ntsb.gov

Accident Databases, Statistics, Reports, and Current and Historical Materials

Aircraft Crashes Records Office—www.baaa-acro.com
Air Data Research—www.airsafety.com
AirDisaster.com—www.airdisaster.com
Airline Safety.com—www.airlinesafety.com
AirSafe.com—www.airsafe.com
Aviation Safety Network—www.aviation-safety.net
AvWeb—www.avweb.com
FindLaw *(US only)*—www.findlaw.com
Flight Safety Information *(FSINFO)*—www.fsinfo.org
Flightscape—www.flightscape.com
JACDEC, Jet Airliner Crash Data Evaluation Center—www.jacdec.de
National Aviation Reporting Center on Anomalous Phenomena—www.narcap.org
The Aero-News Network—www.aero-news.net

Regional and International Associations and Organizations

European Aviation Safety Agency—www.easa.eu.int
European Civil Aviation Conference—www.ecac-ceac.org
European Co-ordination Centre for Aviation Incident Reporting Systems—http://Eccairs-www.jrc.it
European Organization for the Safety of Air Navigation (EUROCONTROL)—www.eurocontrol.be
Flight Safety Foundation——www.flightsafety.org
Global Aviation Information Network—www.gainweb.org
International Air Transport Association—www.iata.org
International Civil Aviation Organization—www.icao.org
International Federation of Air Line Pilots Associations—www.ifalpa.org
International Transportation Safety Association—www.itsasafety.org
Joint Airworthiness Authority *(being phased into the EASA)*—www.jaa.nl
The Latin American Aeronautical Association—www.ala-internet.com/ala2

Confidential Incident Reporting Programs

Australia—www.atsb.gov.au/aviation/asrs
Canada—www.tsb.gc.ca/en/securitas
European Union—www.eucare.de
Korea—www.kotsa.or.kr/air_english/kairs.htm
Taiwan—www.tacare.org.tw
United Kingdom—www.chirp.co.uk
United States—www.asrs.arc.nasa.gov ◆

ISASI Information

OFFICERS

President, Frank Del Gandio (frank.del.gandio.@faa.gov)
Executive Advisor, Richard Stone (rbstone2@msn.com)
Vice-President, Ron Schleede (ronschleede@aol.com)
Secretary, Keith Hagy (keith.hagy@alpa.org)
Treasurer, Tom McCarthy (tomflyss@aol.com)

COUNCILLORS

Australian, Lindsay Naylor (naylor@spitfire.com.au)
Canadian, Barbara Dunn (avsafe@uniserve.com)
European, Max Saint-Germain *(max.saintgermain@free.fr)*
International, Caj Frostell (cfrostell@sympatico.ca)
New Zealand, Ron Chippindale (rc1@xtra.co.nz)
United States, Curt Lewis (curt@curt-lewis.com)

NATIONAL AND REGIONAL SOCIETY PRESIDENTS

Australian, Kenneth S. Lewis (naylor@spitfire.com.au)
Canadian, Barbara M. Dunn (avsafe@uniserve.com)
European, Ken Smart (ksmart@aaib.gov.uk)
Latin American (Vacant)
New Zealand, Peter Williams *(prwilly@xtra.co.nz)*
Russian, V. Venkov (iica-venkov@mtu-net.ru)
SESA-France Chap., Vincent Fave (vincent.fave@aviation-experts.com)
United States, Curt Lewis (lewis@curt-lewis.com)

UNITED STATES REGIONAL CHAPTER PRESIDENTS

Alaska, Craig Beldsoe (craig_Bledsoe@ak-prepared.com)
Arizona, Bill Waldock (wwaldock@msn.com)
Dallas-Ft. Worth, Curt Lewis (lewis@curt-lewis.com)
Florida, Ben Coleman (ben.coleman@faa.gov)
Great Lakes, Rodney Schaeffer (reschaeffer@esi-il.com)
Los Angeles, Inactive
Mid-Atlantic, Ron Schleede (ronschleede@aol.com)
Northeast, David W. Graham (dwg@shore.net)
Pacific Northwest, Kevin Darcy (kdarcy@safeserve.com)
Rocky Mountain, Gary R. Morphew (gary.morphew@scsi-inc.com)
San Francisco, Peter Axelrod (p_axelrod@compuserve.com)
Southeastern, Inactive

COMMITTEE CHAIRMEN

Audit, Dr. Michael K. Hynes (hynesdrm@aviationonly.com)
Award, Gale E. Braden (geb@ilinkusa.net)
Ballot Certification, Tom McCarthy (tomflyss@aol.com)
Board of Fellows, David S. Hall (airsafe1@comcast.net)
Bylaws, Darren T. Gaines (dgaines@natca.org)
Code of Ethics, John P. Combs (mandi2@charter.net)
Membership, Tom McCarthy (tomflyss@aol.com)
Nominating, Tom McCarthy (tomflyss@aol.com)
Reachout, James P. Stewart (sms@rogers.com)
Seminar, Barbara Dunn (avsafe@uniserve.com)
Technical Library, Corey O. Stephens (corey.stephens@alpa.org)

WORKING GROUP CHAIRMEN

Air Traffic Services, John A. Guselli (Chair) (jguselli@bigpond.net.au), Ladislav Mika (Co-Chair) (mika@mdcr.cz)
Cabin Safety, Joann E. Matley (jaymat02@aol.com)
Corporate Affairs, John W. Purvis (jpurvis@safeserv.com)
Flight Recorder, Michael R. Poole (mike.poole@flightscape.com)
General Aviation, William (Buck) Welch (wwelch@cessna.textron.com)
Government Air Safety, Michael J. Cavenagh (mikecav@powerup.com.au)
Human Factors, Dr. Robert C. Matthews (bob.matthews@faa.gov)
Investigators Training & Education, Christine A. Lawrence (Christine.Lawrence@tsi.jccbi.gov)
Positions, Ken Smart (ksmart@aaib.gov.uk)

CORPORATE MEMBERS

Accident Investigation Board, Finland
Accident Investigation Board/Norway
Aeronautical & Maritime Research Laboratory
AeroVeritas Aviation Safety Consulting, Ltd.
Air Accident Investigation Bureau of Singapore
Air Accident Investigation Unit—Ireland
Air Accidents Investigation Branch—UK
Air Canada
Air Canada Pilots Association
Air Line Pilots Association
Air New Zealand, Ltd.
Airbus S.A.S.
Airclaims Limited
Aircraft Accident Investigation Bureau—Switzerland
Aircraft Mechanics Fraternal Association
Aircraft & Railway Accident Investigation Commission
The Ministry of Land, Infrastructure & Transport
Airservices Australia
AirTran Airways
Alaska Airlines
All Nippon Airways Company Limited
Allied Pilots Association
American Eagle Airlines
American Underwater Search & Survey, Ltd.
ASPA de Mexico
Association of Professional Flight Attendants
Atlantic Southeast Airlines—Delta Connection
Australian Transport Safety Bureau
Aviation Safety Council
BEA-Bureau D'Enquetes et D'Analyses
Board of Accident Investigation—Sweden
Boeing Commercial Airplanes
Bombardier Aerospace Regional Aircraft
Bundesstelle fur Flugunfalluntersuchung—BFU
Cathay Pacific Airways Limited
Cavok Group, Inc.
Centurion, Inc.
China Airlines
Cirrus Design
Civil Aviation Safety Authority Australia
Comair, Inc.
Continental Airlines
Continental Express
COPAC/Colegio Oficial de Pilotos de la Aviacion Comercial
Cranfield Safety & Accident Investigation Centre
DCI/Branch AIRCO
Delta Air Lines, Inc.
Directorate of Flight Safety (Canadian Forces)
Directorate of Flying Safety—ADF
Dutch Airline Pilots Association
Dutch Transport Safety Board
EL AL Israel Airlines
EMBRAER-Empresa Brasileira de Aeronautica S. A.
Embry-Riddle Aeronautical University
Emirates Airline
Era Aviation, Inc.
EVA Airways Corporation
Exponent, Inc.
Federal Aviation Administration
Finnair Oyj
Flight Safety Foundation
Flight Safety Foundation—Taiwan
Flightscape, Inc.
Galaxy Scientific Corporation
GE Transportation/Aircraft Engines
Global Aerospace, Inc.
Hall & Associates, LLC
Honeywell
Hong Kong Airline Pilots Association
Hong Kong Civil Aviation Department
IFALPA
Independent Pilots Association
Int'l. Assoc. of Mach. & Aerospace Wkrs
Interstate Aviation Committee
Irish Air Corps
Japan Airlines Domestic Co., LTD
Japanese Aviation Insurance Pool
JetBlue Airways
KLM Royal Dutch Airlines
L-3 Communications Aviation Recorders
Learjet, Inc.
Lockheed Martin Corporation
Lufthansa German Airlines
MyTravel Airways
National Air Traffic Controllers Assn.
National Business Aviation Association
National Transportation Safety Board
NAV Canada
Phoenix International, Inc.
Pratt & Whitney
Qantas Airways Limited
Republic of Singapore Air Force
Rolls- Royce, PLC
Royal Netherlands Air Force
Royal New Zealand Air Force
RTI, LLC
Sandia National Laboratories
Saudi Arabian Airlines
Scandinavian Airlines System
School of Aviation Safety and Management, ROC Air Force Academy
SICOFAA/SPS
Sikorsky Aircraft Corporation
Singapore Airlines Ltd.
Smith, Anderson, Blount, Dorsett, Mitchell & Jernigan, LLP
SNECMA Moteurs
South African Airways
South African Civil Aviation Authority
Southern California Safety Institute
Southwest Airlines Company
State of Israel
Transport Canada
Transportation Safety Board of Canada
UK Civil Aviation Authority
UND Aerospace
University of NSW AVIATION
University of Southern California
Volvo Aero Corporation
WestJet ◆

Embraer Embraces Enhanced Systems Monitoring

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

As an aircraft manufacturer, Embraer is constantly seeking new and innovative ideas that result in added value to its aircraft. With the recent production launch of the Embraer-170, one of the company's concerns was the length of the maturity process that affects all new aircraft models.

The entry into fleet operations of any new airframe platform initially requires additional information in order to ensure expected onboard systems performance during the initial stages of the product lifecycle.

While it is reasonable to expect some degree of "learning" after such a launch, the fact remains that every hour an aircraft is not in service represents a potentially unrecoverable economic loss for the operator.

Recognizing that financial pressures sometimes influence operational decisions, Embraer knew that any efforts to shorten the maturity process must, by definition, enhance flight safety without placing additional demands on the operator.

One initiative was to monitor *every* flight hour of *every* launch 170, for a period of at least 100 flight hours. Technical engineering analyses of performance data would provide the basis for early identification of adverse trends and corresponding corrective actions could be developed and implemented while the fleet density and adverse economic impact would both be low. This would benefit not only the initial launch customers but also would ensure that future customers gain the added value afforded by increased levels of product integrity, quality, reliability, and flight safety.

The culmination of this effort was the AIM-170 program in which routine inflight recorded data collection and subsequent engineering analyses of onboard systems in terms of performance and condition monitoring will help Embraer to refine and improve the systems performance of the 170, while reducing unscheduled maintenance requirements and aircraft downtime. Fortunately the amount of digitally recorded data available in the Embraer-170 provides an additional means to monitor aircraft systems condition to a degree not previously feasible.

Proprietary AGS software will perform the raw flight data processing and automatic analyses based on the 170 systems limits and expected performance parameters as established by engineering staff. Some of the main capabilities—

- performs computation for derived parameters using recorded parameters.
- three levels of exceedance limits are used to detect abnormal events.
- internal airport and runways database.
- built-in detected events database.
- built-in statistical graphics and report editor.

A series of 190 logic detection rules has been designed in such a way that abnormal aircraft system behavior can be identified. The data collected can also be used as a basis for specific engineering analyses and statistical studies providing support for the in-service difficulties solution process.

The recently launched EMB-170.

The technical engineering analyses of inflight recorded data provide the basis for early identification of adverse trends so that corresponding corrective actions can be developed and implemented while the fleet density and adverse economic impact are both still relatively low.

At this time, due to the excellent participation of Alitalia Express and LOT Polish Airlines, Embraer obtained its first positive analysis, which reflected a growing mutual trust between the air safety departments of the manufacturer and the launch customers operating this new aircraft. There has been a commitment to ensure the confidentiality of all inflight data as well as the resulting analyses.

Embraer emphasizes, however, that the AIM-170 program is not a FOQA program. The monitoring of crew performance and operational exceedances is still the responsibility of the operator.

Embraer is committed to providing safety as a value-added feature of every aircraft delivered. ◆

AIR SAFETY INVESTIGATORS
INCORPORATED AUGUST 31, 1964

ISASI
107 E. Holly Ave., Suite 11
Sterling, VA 20164-5405
USA

NON-PROFIT ORG.
U.S. POSTAGE
PAID
Permit #273
ANNAPOLIS, MD