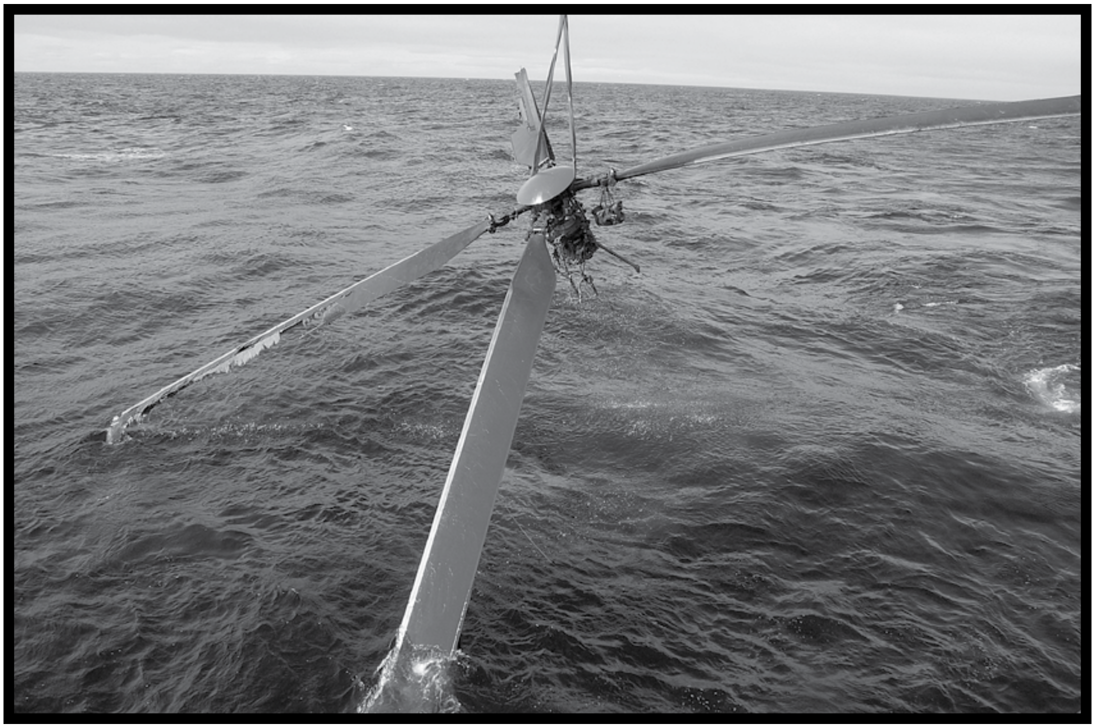
ISASI FORUM
"Air Safety Through Investigation"

JULY–SEPTEMBER 2013



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ABOUT THE COVER

The holistic approach to aircraft accident investigation was used by the AAIB during the investigation of an Aerospatiale (Eurocopter) AS332 L2 Super Puma that crashed in the North Sea 11 nm northeast of Peterhead, Scotland, in April 2009. Shown is the recovery operation of the main rotor head and blades from the North Sea. The helicopter suffered a catastrophic failure of the main rotor gearbox as a result of a fatigue fracture of a second stage planet gear in the epicyclic module. The AAIB finds the holistic approach worthwhile in the timely proactive safety action taken to prevent recurrence (see page 4). Photo courtesy of the AAIB, UK

ISASI FORUM
"Air Safety Through Investigation"

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AIR SAFETY
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ISASI Upgrades Member Communications Effort

By Frank Del Gandio, ISASI President

On May 3, 2013, ISASI's International Council approved the launch of an electronic newsletter to be distributed to members by e-mail. This offers an excellent opportunity to provide more timely information about ISASI activities to all of our international members. The newsletter, for now, is to be titled *ISASI Update*. But after the first few issues, you will be asked to help provide a permanent title. Electronic communication is about access, speed, and convenience. But it's also about brevity. A strong advantage of electronic communications is the ability to instantly link to ISASI's website—as well as to other related information sites or articles of interest to enrich your reading experience. The newsletter will be delivered to your e-mail address that we have on file. So please ensure that the e-mail address appearing on the website (www.isasi.org) in the individual database of the "members only" section is correct.

The addition of the electronic newsletter gives us several platforms with which to reach you: *ISASI Forum,* ISASI's website; ISASI's Twitter page, ISASI's annual seminar, and ISASI Reachout. Each has its separate role to fill, but all will interact to form and support a unified member communications program. The melding of all of our communication tools will greatly help achieve our goals of providing information of value to you, to educate and to inform about our profession, and to bolster ISASI's image among its air safety investigation publics.
As part of the change, the "ISASI Roundup" news section you are used to reading in *ISASI Forum* will move to the Society's website beginning with this issue. It can be found under "ISASI Roundup" and will be updated as frequently as information becomes available. In this regard, I ask that you share the news of your profession with fellow members by making submissions that will be used "as is," or rewritten if necessary, and posted on our website's ISASI Roundup section or be used in our other communications vehicles. The newsletter and Twitter page will also draw from the Roundup section for publication, as appropriate.

The success of this effort, however, largely depends on all of us. The life's breath of any communications tool is its content. The timely and continual collection of useable content material is crucial. And we need to rely on you to help provide that content. Submit any material you consider appropriate to Marty Martinez at espmart@comcast.net. The type of information that you might consider submitting—

- individual member activity that involves/celebrates the profession.
- success stories of members, societies, corporate members related to the profession, etc.
- awards received/awards bestowed.
- planned upcoming events/appearances.
- speeches to be given/that have been given.

ISASI 2013

On August 19, the Society's 44th annual international conference on air accident investigation will open in Vancouver, B.C., Canada. This conference is devoted solely to topics that affect our profession of air safety investigation. Each of the three days of technical sessions will be opened by a keynote speaker representing the state regulatory agency of Canada, Korea, and France. In addition to the 15 technical papers being presented, three panels will discuss various topics dealing with preparing the next generation of investigators and protecting sensitive information. Our most coveted Jerome F. Lederer Award will be presented on the last evening of the technical program.

The addition of the electronic newsletter, *ISASI Update,* gives us several platforms with which to reach you: *ISASI Forum,* ISASI's website; ISASI's Twitter page, ISASI's annual seminar, and ISASI Reachout. Each has its separate role to fill, but all will interact to form and support a unified member communications program.

Two tutorial workshops will precede the technical program. Separate registration is required for the tutorials. Attendees of the first tutorial will receive information directly pertinent to the investigation of composite failures and lessons learned. Topics will include a case study of the investigation of a loss-of-rudder serious incident, the technology of composite structures and failure mechanisms, investigator safety issues, the safe handling of hazardous components, and manufacturers' views of new technologies.

Our own Military Air Safety Investigator Working Group is involved in the second tutorial. Speakers from worldwide military aviation organizations will address military-specific aviation safety issues. Topics will include, among others, mishap investigation, proactive and reactive flight data analysis, programs to detect hazards, safety audits, quantification of risk, emerging issues with new technologies, safety data sharing, military aviation human factors, and unmanned aerial systems.

Registration to attend this exciting conference is still open. Full details are on the ISASI website. Take a few minutes to look it over and note all of the other great activities that will take place. And as always, don't hesitate to contact me with any questions, comments, or advice you may have regarding this message or other Society activities. I can be reached through my e-mail: frankdelgandio@verizon.net. ◆

A HOLISTIC APPROACH T ACCIDENT/INCIDENT INVES

The AAIB has successfully used the holistic approach, which encourages stakeholders' involvement in the accident investigation, including analysis and gathering of factual evidence, but in a way that does not conflict with the independence of the state investigating authority.

By Phil Sleight, Principal Inspector of Air Accidents at the Air Accidents Investigation Branch, UK

(Adapted with permission from the author's paper entitled A Holistic Approach to Aircraft Accident/Incident Investigation *presented at the ISASI 2012 seminar held in Baltimore, Maryland, USA, on Aug. 28, 2012, that carried the theme "Evolution of Aviation Safety, From Reactive to Predictive." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org under the tag "ISASI 2012 Technical Papers."—Editor)*

For air accident investigation, the most common system that is employed by Safety Investigation Authorities (SIA) involved in major investigations is the group system model. This is the system that is advocated by the current ICAO *Manual of Aircraft Accident and Incident Investigation.* It is easy to follow and does result in a reasonably thorough and consistent investigation.

Usually the Investigator-in-Charge (IIC) initiates and commands a set of standard groups, each of which has an SIA chairman who is an investigator with a specialty in the subject area on which the group is based. Investigators, accredited representatives, and advisors are then placed into these groups to gather and provide the factual information to the group chair.

In this system, each group is assigned the task of gathering the evidence only for its particular area of specialism, and in most cases produces "field notes" agreed to by all the group members to be subsequently presented to the IIC. The advantage of the system is that all the factual evidence, whether it is relevant or not, is documented for use by the IIC. The expectation is that nothing will remain unrecorded, so that a full analysis of all the facts can be carried out.

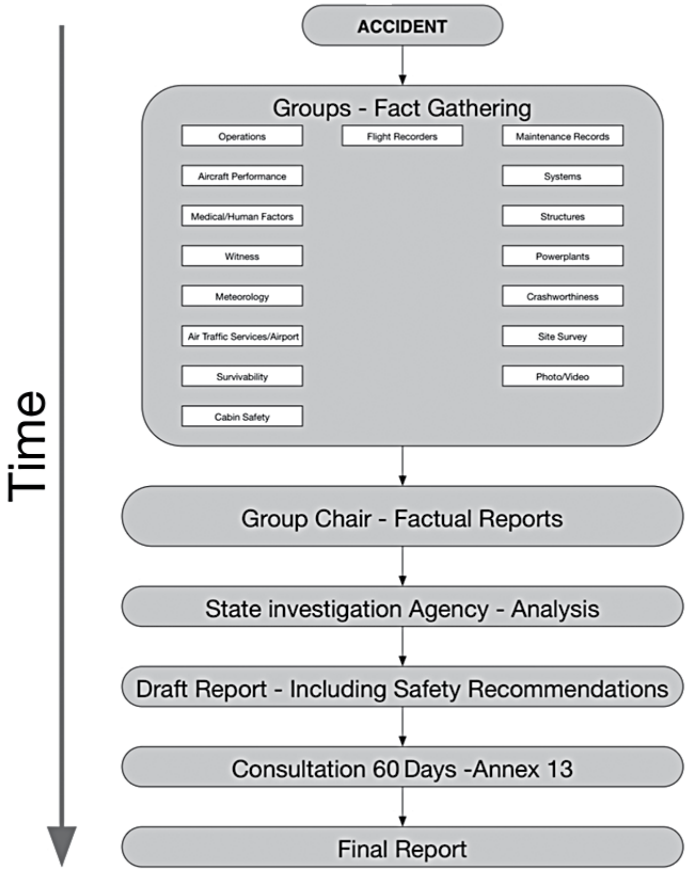

Figure 1. Flow chart of the common approach

The disadvantages are that it can take a long period of time for the group reports to be produced and it is labor intensive, so it uses a lot of resources—something most SIAs do not have access to. The system of specialist groups only dealing with the facts within their specialism can also promote a "silo" attitude, as each group focuses on its own particular area and does not communicate effectively with other groups. The IIC then becomes the only person in the investigation who has the overall "big picture view" of the investigation.

Moreover, members of a group are often isolated from other aspects of the investigation, so advisors from manufacturers and regulators may not receive the full information on specialist

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TO AIRCRAFT
STIGATION

areas that may at first appear to be outside of their specialism, but which might be important to their understanding of the circumstances.

There is usually no analysis carried out amongst the groups until all the facts are gathered and group reports are produced. The analysis then takes place, in some cases without discussion outside of the immediate SIA team, and in some cases the accredited representatives are involved. The process does not allow iteration as it is assumed all the facts have been gathered and can be quite time consuming. It is only after the analysis that safety issues are identified and the potential safety recommendations produced. The whole process takes time, and it may be a matter of months before the group chairs produce their final agreed to factual reports before any analysis takes place. It is only after analyzing the facts that any safety issues are identified and safety recommendations produced.

Reason for different approach

The common approach described above focuses on a rigid structure for the gathering of factual evidence. Due to its rigid and bureaucratic nature, it can take weeks or months to gather the facts before any analysis takes place. Therefore, the investigation team can be distracted from the early identification of the safety issues that may need to be addressed. Indeed, in many cases the analysis of the factual evidence is carried out only by the experienced investigators of the investigating SIA, with little reference to the specialist expertise of the other parties to the investigation.

To successfully identify a safety issue, the full cooperation of the manufacturer at all stages of the investigation is essential.

Aircraft are becoming more complex with the use of advanced avionics systems, interconnected networked systems, and exotic materials. For these advanced and complex aircraft, the knowledge of the system or materials sometimes only lies with the manufacturer. So to successfully identify a safety issue, the full cooperation of the manufacturer at all stages of the investigation is essential.

Once a safety issue is identified, the aim would be to address the issue to prevent recurrence of the accident. In some cases this will require the regulatory authorities to take early and immediate action, something that can only be done if they are involved in the investigation process and are aware of the findings. Indeed, the regulator can provide valuable input on interpretation of rules, regulations, and certification requirements and how they were applied or meant to have been applied when the aircraft, engine, or system was first designed.

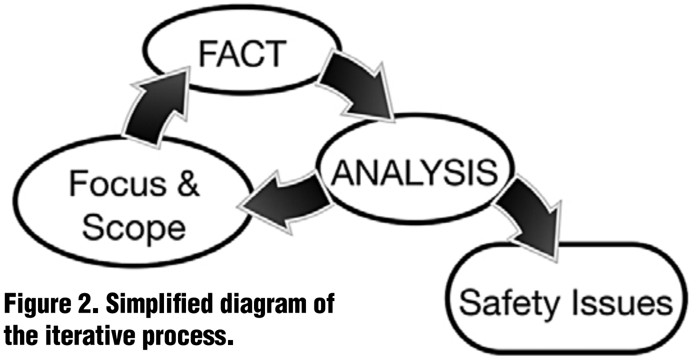

Figure 2. Simplified diagram of the iterative process.

Holistic approach

With a holistic approach, each stakeholder is very much part of the analysis as well as the gathering of factual evidence. The investigating state's investigators take the lead and determine the direction of the investigation, thereby maintaining the independence. However, this is an iterative approach, with analysis being conducted as the facts are gathered. The holistic approach encourages the engagement of all the parties at an early stage of the investigation, which then continues throughout the investigation process.

So as soon as possible after the accident, the potential parties are notified and encouraged to participate. For a large investigation, a form of the initial group system is employed with an IIC; lead inspectors for operations, engineering, and recorded data; and group chairs assigned to each of these general areas. However, there is no defined set of groups. The assignment of groups comes about as the factual information begins to be known, which requires a certain amount of analysis of early factual information.

It is usually known within a few hours what the basic facts of the flight were, which provides an early indication of the likely direction of the investigation. This means the IIC can focus the resources on that area that is likely to yield the most safety benefit. This cannot be done by the investigators in isolation.

As aircraft become more complex, with systems interactions and operations now inextricably linked, as well as a preponderance for recorded data, some of which is not held on the aircraft itself, there is a need to ensure that all relevant parties are engaged. So although there are "groups," the information within each group needs to be shared amongst the other groups and parties. This "holistic" approach is such that everyone involved is given the opportunity to be made aware of the information that is being gathered by the investigation. Indeed, participants are encouraged to discuss the investigation openly and provide their point of view.

This approach is iterative involving the gathering of facts, analyzing these facts, and then determining the focus of the investigation as to the continued gathering of further facts, tests, or research. This "focus and scope" stage also enables the reassignment of resources to maximize the efficient collection of evidence for those areas that will produce the most safety benefit.

This system is such that there is a possibility that the investigation team may become too focused on one aspect and miss other essential factual evidence, which may later be relied upon. Hence, the need still exists to gather factual evidence that would otherwise be destroyed and that this evidence is identified early and suitably gathered. Early engagement with the manufacturers has shown to be valuable in identifying this evidence. Also, it is advisable to protect the evidence even if at a later date it is no longer required by the investigation.

As the investigation progresses, the various parties will be fully aware of the gathered factual evidence and also the direction of the investigation. Their input allows for differences to be aired and for worthwhile discussions to take place across groups and advisors.

As with other approaches, the model shows that the process starts with the establishment of groups to gather facts. However, rather than a fixed set of groups, the initial groups develop as information about the accident becomes known, with some groups having only a short life. To maximize resources, multiple groups may also be chaired by the same investigator by the SIA, and, indeed, participants may also be included as part of multiple groups. Once gathered, facts are then analyzed by the "investigation team," which includes the accredited representatives, advisors, and parties to the investigation, and not group by group but across groups. This holistic approach is to ensure that each group is aware of the factual evidence gathered by the other groups.

During the analysis of the facts are three possible outputs:
1. The definition of the further scope and focus of the investigation, which includes the assignment of more resources, the reallocation of the existing resources, the closing down of groups that no longer serve a purpose, and the release of resources for other investigations.
2. Identification of safety issues and the encouragement of safety action by the relevant participants. Indeed, it is also at this stage that the possibility of reporting on the identified safety issues may be relevant, through interim reports or statements.
3. Comparison of the findings determined by the factual evidence.

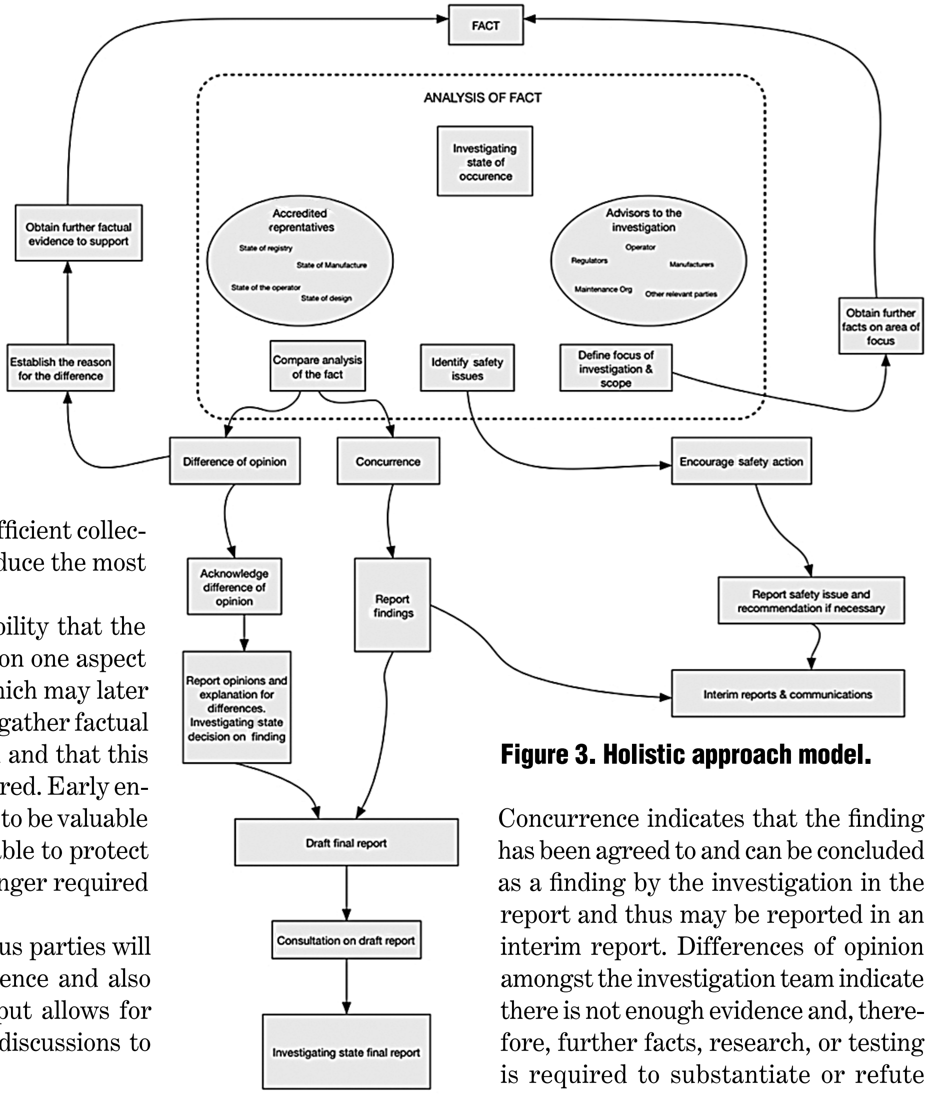

Figure 3. Holistic approach model.

Concurrence indicates that the finding has been agreed to and can be concluded as a finding by the investigation in the report and thus may be reported in an interim report. Differences of opinion amongst the investigation team indicate there is not enough evidence and, therefore, further facts, research, or testing is required to substantiate or refute the position. There is also the possibility that some doubt exists about the findings from the factual evidence that has been gathered. The SIA, who are conducting the investigation, will determine the findings to be reported to maintain the independent nature of accident investigation. However, once a difference of opinion has been identified, it can be taken forward and if not resolved, may objectively be presented in the final report.

The process is iterative, with facts being analyzed as the investigation progresses.

Having completed the process and reached a stage at which the required factual evidence has been gathered, the draft final report is produced by the SIA using the agreed to findings. The report will also include the findings that have been determined by the SIA, but may not be fully agreed to upon amongst the participants. However, as the report will also include these valid differences of opinion on the analysis and the reasons for these, then the report is balanced.

Benefits of the approach

The main benefit of the holistic approach is that parties to an investigation that have the power to carry out safety action are fully engaged with the investigation— including not only the factual evidence as it is gathered, but also the analysis of the facts so that they become aware of the safety issues at an early stage. Indeed, the parties may also highlight safety deficiencies that require further research that may have otherwise been missed by the investigation teams. This means that regulators, for example, are able to issue mandatory action early and with the full agreement of the investigation team, rather than waiting for the factual evidence to be presented in a report or safety recommendation.

At the AAIB, our philosophy is now moving toward encouraging taking proactive safety action when the facts are known, rather than the reactive action following a safety recommendation, which could be several years after the accident. This proactive approach means that rather than issuing safety recommendations that have no indication of whether they will be adopted or not, reporting on safety action that has taken place means the reader understands that safety has in fact been improved based on the factual evidence.

With a focused holistic approach, only those areas that have a safety benefit are carried forward into a full analysis for the identification of safety issues. Thus, the report is more focused and doesn't stray into reporting factual details on areas that had no bearing on the accident/incident. Another advantage is that there is an efficient use of the resources available to the investigation team, with the focus primarily on the main safety issues that caused or contributed to the accident.

With a focused holistic approach, only those areas that have a safety benefit are carried forward into a full analysis for the identification of safety issues.

As the parties to the investigation have been involved from the beginning, the investigating SIA become aware of areas of potential conflict/controversy early on. This enables the SIA to understand the reason why such a conflict/controversy exists and to acknowledge it. There will always be cases where a participant will try to influence the content of the report with conclusions that are not based on the factual evidence. The holistic process identifies such conclusions sufficiently early that they are dealt with well before the report is about to be published. The involvement of all parties during analysis discussions can mean that the analysis remains balanced and is not biased toward one point of view, and that it is verified by the inclusion of the regulator and other specialists.

Only those conclusions that are validated by the factual evidence should be reported, but there may be differences of opinion of the established facts. The SIA can then incorporate those valid areas of differences of opinion into the main report to balance the views of other parties. The advantage is that it is then less likely that the other states to the investigation will criticize the report and request the appending of substantiating comments to the report. The appending of comments only detracts from the aim of the investigation, which is the timely promulgation of safety information.

Indeed, the holistic approach allows for full and free discussion of the issues and open dialogue following the formal consultation phase. Also, at this stage a rapport has built up amongst the investigation team and the parties, which has shown to lead to more open dialogue than would otherwise have taken place.

Maintaining independence

Although the holistic approach encourages full engagement with parties to the investigation, it is still important that the investigating SIA maintain independence from the other participants and also remain objective.

Still, certain parties will have their own perspectives, cultural differences, and agendas for the investigation and will attempt to influence its direction. However, the holistic approach should identify these traits early in the investigation because the parties are all fully engaged from the start. Indeed, in our experience this approach has highlighted areas of contention at an early stage and allowed for the investigation to deal with them during the investigation process, rather than at the end when the final report is being drafted.

It is the function of the IIC to make sure that no one party has a strong influence on the direction of the investigation and to make sure the viewpoints of all are taken into consideration. The IIC should also be able to identify when a certain party may have overstepped the mark and take necessary action, which could include expulsion from the investigation process.

The final word always remains with the investigation SIA. They should reserve the right to exclude parties to the investigation or indeed to manage the relationships to avoid what could be destructive conflict. It is the skill of good investigators to know when they are being misled or not being given the answers they need to further the investigation. It always remains that the investigating SIA can produce recommendations for safety action should they feel it is necessary for continued aviation safety, even if other parties are not in agreement with the recommendations.

Confidentiality

For a holistic approach, it is important that the participants maintain confidentiality of the investigation's information and the analysis discussions. Care still needs to be taken with regard to the information flow, as certain information may be protected from disclosure by local regulations and may not be shared out-

A HOLISTIC APPROACH TO AIRCRAFT ACCIDENT/INCIDENT INVESTIGATION

side of the direct investigation team; so at times advisors and observers may have to be excluded from certain discussions. However, they are likely to receive a summary of these areas, provided it is permissible within the regulations.

Should confidentiality be breached, either by leaks or by the unapproved release of investigation information, the trust between the parties also breaks down. This results in the investigation participants becoming insular and the sharing of information effectively dries up—or is carefully scrutinized before its release to the other parties. This then leads to further delays as the information flow disappears, and at worst the needed expertise could be removed.

The result of this is a slowing down of the investigation process and delays in identifying the safety issues, thereby reducing the timeliness of safety action. Thus, a situation is created that is detrimental not only to the investigation process, but also to the aims of the investigation, the investigation team, and the other participants.

In the European Union, the rules on confidentiality are laid down in the EU Regulation EU 996/2010, Articles 14 and 15. In addition ICAO Annex 13 lays down the following for international participants: *"Obligations—5.26 Accredited representatives and their advisors: a) shall provide the state conducting the investigation with all relevant information available to them; and b) shall not divulge information on the progress and the findings of the investigation without the express consent of the state conducting the investigation. Note—Nothing in this standard precludes prompt release of facts when authorized by the state conducting the investigation, nor does this standard preclude accredited representatives from reporting to their respective states in order to facilitate appropriate safety actions."*

To ensure confidentiality, any participant to a large investigation should be bound by these confidentiality requirements and may be required to sign a statement reminding them of their entitlements as laid down by local and international protocols.

Communication challenges

Good communication in a holistic investigation is the key to its success and when put into practice should not result in problems of information "vacuums." These vacuums can, at worse, mean that frustrated participants in an investigation take matters into their own hands and either leak information or produce their own interpretation of events that then finds its way into the public domain. The rules on disclosure of information are laid down in Europe under EU regulation 996/2010 and ICAO Annex 13; however, this does not stop certain organizations from issuing their own "spin"—hence the need for confidentiality statements at the beginning of the investigation as mentioned previously. It is important that no information relating to the investigation be released by participants or their organizations without the express approval of the IIC.

There are two challenges in any investigation— communication with the investigation team and parties and external communication. The holistic approach, due to its model of inclusivity, means that issues of communication can be resolved quickly.

Internal communications amongst the investigation team and participants will ensure the holistic approach works well. This is usually easy to accomplish at the accident site during the field phase, as the participants are all located in one place and a daily, or twice daily, brief chaired by the IIC can take place.

In summary, the holistic approach has been shown to be an efficient way of engaging with all the parties involved in an investigation. It encourages all the investigation parties… to work together not only in the gathering of facts but also the analysis.

During these daily briefing/meetings, the factual evidence gathered during the day can be discussed and analyzed and decisions made as to the future direction of the investigation effort. The meetings also permit the parties to highlight safety issues and indicate what safety action is being developed or issued. Further, the investigation team can then coordinate its communication strategy for external release of information.

Once the field phase is complete, the internal communications become more challenging because the "momentum" of an investigation starts to lessen as people return to their day-to-day working style. This can lead to the parties becoming insular and distanced from the investigation work.

As part of the holistic approach, the IIC can maintain investigation momentum by ensuring that all the parties continue to work closely together and share factual information and analysis. Also, at this stage, time zones can become an issue with up to 12 hours' difference between locations. A compromise is to have regular daily or weekly telephone conference calls at a mutually convenient time, using web-based presentation-sharing tools to assist in the sharing of the factual information.

Although conference calls work well, the ideal is to meet face-to-face, which is an integral part of the holistic approach. A face-to-face meeting not only brings the investigation team together in one place, but also enables other discussions to take place amongst parties to clarify small points of dispute, which would otherwise have not taken place. It also builds rapport and enables an understanding of each party's position with good open discussion, or indeed private discussion on particular points if felt necessary.

The face-to-face meetings provide a good point at which to refocus the investigation and again review the safety issues identified and the areas that are either being addressed or are likely to be addressed. It enables discussions and coordination of the external communication strategies of each party.

This worked particularly well for the AAIB on the investigation into the accident to a Boeing 777 G-YMMM at London Heathrow, where following the field phase and due to the geographical spread of the various participants, daily and weekly telephone conferences kept the momentum to a certain extent. However, bringing all the parties together routinely at face-to-face meetings was very successful in the promulgation of pertinent information. Indeed, as the value of these face-to-face meetings became evident, there were times that requests were made by parties for more frequent meetings. To reduce the impact on the work being carried out—as travelling to a meeting does take up valuable investigation time—the face-to-face meetings would sometimes be held at the location where the work was being carried out, i.e., fuel labs, engine test labs, research facilities, but mostly they were at neutral venues.

The need for regular meetings is recognized in the ICAO *Manual of Aircraft Accident and Incident Investigation*: "*4.5.2—It is always a challenge to ensure that the investigation continues to progress following the field phase, for the most part because the members of the investigation team are no longer centrally located, and subject-matter expertise is no longer readily available. As a result, the group chairpersons and the Investigator-in-Charge will have to increase their efforts to maintain communication with team members and to ensure that investigation tasks are completed on time. In this regard, the Investigator-in-Charge should have frequent, regularly scheduled, decision-oriented team meetings, and have additional meetings for significant issues or for issues that will require a change to the investigation plan.*"

The most important stage in which communication can sometimes be lacking between participants is when the final report is being brought together. Again, a face-to-face discussion is part of the holistic approach and has proven to work well. The approach means that the SIA share findings with all the parties and allow for acknowledgement and understanding of any disagreements and the presenting of their final decision.

This can then be followed up by a further meeting following the formal consultation phase of the report to again discuss any areas of particular disagreement and to clarify any points that may be lost in translation—especially with states where English is not their first language. The experience of this approach shows that there is less likely to be a need for comments to be appended to the final report.

The holistic approach, as stated earlier, also allows for coordinated communication strategies. This means that should a party wish to issue something that addresses a safety issue, the SIA can simultaneously issue an interim report with the facts and analysis presented to support the action. The other parties can then use this to prepare statements to customers and the news media. The result is the correct impression that cohesiveness exists within the investigating team, allowing for the early identification of and timely attention to safety issues. The approach also allows for the investigation team to be aware of pressures on the parties to the investigation so that the SIAs' communication strategy can be altered accordingly. This could mean the early publication of short factual reports or the release of presentations by the IIC.

In summary, the holistic approach has been shown to be an efficient way of engaging with all the parties involved in an investigation. It encourages all the investigation parties, including the manufacturer, regulator, operator, etc., to work together not only in the gathering of facts but also the analysis. The benefit is the timely identification of safety issues and the early engagement with those who are able to carry out safety action to prevent recurrence, without having to wait for the publication of the final report. The AAIB has used this approach for the majority of its investigations, and it has proven to be worthwhile in the timely proactive safety action taken to prevent recurrence. This is particularly true in the investigation of the Airbus A340 G-VATL accident in 2004, the Boeing 777 G-YMMM accident at Heathrow in 2008, the AS332 L2 G-REDL accident in 2009, and the recent ditching of the EC225 G-REDW in 2012.

However, this is not a new approach. The 1970 edition of the ICAO *Manual of Aircraft Accident and Incident Investigation* included the following: "*The maintenance of a high standard of air safety is dependent amongst other things upon the appropriate corrective action being taken when faults or shortcomings in the design or maintenance of aircraft are brought to light or when unsatisfactory procedures for their operation are revealed. Since an aircraft accident represents the very antithesis of air safety, it is most important that adequate and relevant measures are taken expeditiously to prevent a recurrence arising from a similar cause…. At frequent intervals during the investigation, the Investigator-in-Charge should hold meetings to review the progress of work and to permit free exchange of ideas and information among the groups. Very often one group will have uncovered some factor facts that will serve as a valuable lead to another group in their work. In this manner, all the relevant facts, conditions, and circumstances relating to the accident are progressively developed.*" ◆

'Defying Gravity, Safely AND Surely'

By Deborah A.P. Hersman, Chairman, U.S. National Transportation Safety Board

(Adapted from Chairman Hersman's presentation before The Wings Club in New York on June 12, 2013, and presented here for the air accident investigation perspective it provides.—Editor)

In 1942, when your first leaders were drawing up the club's bylaws, unlike today, the trip to the airport was the safer part of the journey. Now, fast-forward to 2013. Talk about the spirit of St. Louis: Every day, the equivalent of the population of the St. Louis area—more than 2 million—are aloft on U.S. airlines, defying gravity, safely and surely.

Today's safety record has been achieved through the work of Wings Club members and the entire aviation community—operators, manufacturers, regulators, labor, service providers and, yes, the independent accident investigator.

As David Hinson outlined in the 32nd Wings Club Sight Lecture, a host of developments brought us to today's record—improved airframes and engines, enhanced technology for air traffic control, weather detection, simulated flight training, and more. There's also a greater appreciation of human factors with improved practices, such as crew resource management. Yet, how did commercial aviation learn it needed these improvements?

Most of the lessons were hard-earned…and learned…through crashes, lives lost, and tarnished records. Accidents followed by painstakingly thorough and transparent investigations conducted by the investigator who Congress specifically created to be independent. Independence, which is essential to the NTSB's effectiveness in finding out what happened—and why—and recommending a path toward the solution.

That's what I want to talk about today: defying gravity and building upon today's strong commercial aviation safety record. And about the unique role played by the NTSB: 400 people you may likely never meet, 400 people you may not want to know, but 400 people you need to know about.

Since 1967, the NTSB has conducted more than 132,000 aviation investigations and issued more than 13,000 safety recommendations. Each year we investigate about 1,400 general aviation accidents, and we assist in dozens of foreign investigations around the world. Right now, we are supporting efforts from Bagram to Bali and from Paraguay to Pakistan.

ICAO Annex 13 establishes a framework for working with our international counterparts, whether it is an Airbus event in the United States or a Gulfstream event in Germany. The value of U.S. participation in foreign investigations is that we can identify issues before they become problems here at home. In short, NTSB participation provides U.S. stakeholders with access to early findings and advances the safety of U.S. products.

Yet, with the last fatal U.S. airline crash—Colgan Air near Buffalo—52 months, or some 40 million flights ago, some may think that the NTSB and independent investigation is "so last century." And I know that at times, with the NTSB's independence and transparency, you may love us or loathe us.

If we're investigating your operation, your product, or your client, the spotlight is uncomfortable…. But in other investigations, where the focus is elsewhere, the findings and fixes may help you, the broader aviation community and, most importantly, air travelers. Recall the Alaska Airlines MD-83 plunging into the Pacific Ocean in January 2000…. Our investigation was just starting, yet there was consensus among the team that the jackscrew assembly had experienced unusual wear. The result: operators promptly changed maintenance procedures on their MD-80 series aircraft. Safety was served. Who knows how many lives were saved?

Yet, love us or loathe us, commercial aviation needs us. It is those 730 million passengers who fly on U.S. airlines each year, which the NTSB represents, [who] count on an honest broker with the ability to identify existing and emerging safety issues and to push for needed improvements…and to keep them informed.

The FAA has investigators. Industry has investigators. But as the independent safety investigator, the NTSB is able to ask the tough questions and challenge the community to find solutions to crucial safety issues. In our investigation of the 2009 Colgan Air crash near Buffalo, we asked a lot of tough questions about pilot training and professionalism, about standard and sterile cockpit procedures, about pilot records, and more.

But perhaps the toughest question was about pilot commuting. How can you be rested and ready for duty when you slept the previous night in a lounge chair and were up at 3 a.m. sending e-mails or when you commuted the night before from Seattle to Newark via FedEx through Memphis? We asked: Shouldn't there be better regulations for flight crew rest and addressing fatigue?

It's because of that congressionally endowed independence that the NTSB can ask the tough questions. Sometime we raise issues that one side doesn't want to talk about. Other times, we raise issues that no one wants us to talk about. And there have been times when we've pushed ahead while others have retreated. That's because the NTSB's only stake in the outcome is preventing the next accident.

Next, [baseball] umpires don't go into that line of work to win popularity contests. They do it to make a difference and to ensure fairness on the field…. Aviation professionals come to the NTSB to make a difference and to enhance safety in our skies. Just as umpires call "balls and strikes," the NTSB calls them as we see them, from a position of neutrality with an unbiased up-close view of the action.

Here's an example of a "called strike." In our investigation of the October 2004 crash of a Pinnacle Airlines repositioning flight, we highlighted the pilots' unprofessional behavior: flouting the rules and taking the aircraft to its certification ceiling: Flight Level 410. We've called "out" controller professionalism as well, such as when in 2009 a controller in the tower was distracted by personal phone calls and a private plane and a helicopter collided over the Hudson River, killing nine people.

Lastly, challenging the community to find solutions. We conduct investigations, follow the facts, and flag the issues. For example, mid-air collisions. For decades, investigators went to repeated wreckage sites caused by mid-airs. Those investigations highlighted the need for a fix so that pilots could quickly respond in close-call situations. But it took decades before industry applied its ingenuity and responded with TCAS.

Similarly, there were repeated CFIT crash investigations and NTSB calls to warn pilots of approaching terrain. The response—TAWS, and then even more effectively, enhanced ground proximity warning systems—saved countless lives.

In the TWA 800 investigation, we determined that the center wing tank's flammable fuel/air mixture ignited to cause the explosion. We called for a fix, and in time, the FAA and industry engineers figured out how to reliably and more economically develop an inerting system. And [there's] the American Airlines crash in Belle Harbor in 2001. Following the investigation, we challenged Airbus to make the rudder system on its A300 and 310 aircraft safer. It did. Airbus installed a monitoring system that warns pilots who reverse their rudder inputs.

It used to take dozens of crashes and decades between problem identification and solution. But today, the responses are expected to be much quicker. For instance, when we flagged New York City airspace issues after that 2009 mid-air, the FAA put together a workgroup and made changes within months.

The party system allows the board to obtain additional expertise and provides stakeholders a window into the investigation. Allowing them to see early, and firsthand, the evidence they may need to take corrective action, such as in April 2011 when the fuselage on a Southwest Airlines 737 ruptured. The plane diverted and landed safely in Yuma. Our investigators found a 9-inch by 5-foot hole. Next, our lab's close examination of the skin found fatigue cracks emanating from rivet holes. Within days, the FAA issued an emergency airworthiness directive requiring lap-joint inspections. These inspections revealed cracks in several airplanes, which were immediately removed from service and repaired.

Safety was served

I mentioned the importance of identifying and understanding emerging safety issues, which can be a challenge with the growing complexity of aircraft, engines, components, systems, and more.

That's why on January 7, when we learned about a lithium-ion battery fire on a JAL 787 at Boston Logan, we immediately took a look. Fire on an aircraft is never a good thing. And the 787 is a new airplane with, as Boeing describes it, "a suite of new technologies and revolutionary design." We needed to know more. Was the battery fire a "ball or a strike"? We couldn't know unless we checked it out.

On January 11, the FAA announced it would conduct a comprehensive review of the 787's critical systems, including their design, manufacture, and assembly. At the same time, the FAA voiced its confidence about the 787's safety. Then less than a week later, on January 16, as we were tearing down the JAL battery, an ANA 787 performed an emergency landing after the pilots received warnings about smoke and a fault in the battery system. We sent an investigator to Japan to serve as an accredited representative on the JTSB's investigation. ANA and JAL grounded their 787s. The next day, the FAA issued an emergency airworthiness directive for 787s to cease further flight.

The FAA grounds a U.S. fleet

The first time a U.S. aviation authority grounded a fleet was after a fatal Lockheed Constellation crash in 1946. The second grounding came 33 years later, after the 1979 Chicago DC-10 crash that killed 275 people. This year, 34 years after the DC-10 grounding, we see only the third commercial grounding in U.S. history. This is big. And the pressure was, and is, intense to get to the root of the problem. Two incidents in two weeks on two operators' aircraft. Is it a ball or a strike?

In today's global aviation environment, with so much at stake, it's crucial to conduct a thorough, objective, and, yes, independent investigation. We sent investigators to the battery manufacturer in Japan...to the battery integrator in France…[and] to the battery charger manufacturer in Arizona. We sent multiple teams to meet with Boeing in Seattle. And we brought in outside battery experts.

> **"There's no credit from the public for past achievements. Airlines are only as good as their last flight. What happens today is a given, and continued improvement is expected to safely defy gravity tomorrow."**

In April, we held a forum on lithium-ion battery technology and then an investigative hearing on the 787 battery fire, which brought more experts and more light to bear. We released an interim factual report in March, and we plan to release the final report before the end of the year.

But here's what strikes me about the 787 battery story—which is still to be fully told—it is the sign of how risk intolerant we have become. As air travel becomes safer and safer, the tolerance for risk, for failure, is reduced. Look at the biggest difference between this FAA grounding and the last one in 1979.

No one died

We live in a different era now. We've seen 52 straight months without a fatal U.S. commercial accident. There are higher standards today. And greater expectations. Much greater. Yet, the absence of accidents does not equal safety. Safely defying gravity thousands of times each day requires constant vigilance. That's because risk remains and always will. What the aviation community has done is learn and apply effective ways to mitigate many of the risks that we've identified.

And there's no credit from the public for past achievements. Airlines are only as good as their last flight. What happens today is a given, and continued improvement is expected to safely defy gravity tomorrow.

The consequences of failure can be dramatic. Yes, loss of life and injuries, but also loss of business and hard-earned public confidence. But there are no "miracles" in modern aviation. The remarkable safety record is the result of a lot of hard work by a lot of players. ◆

Accident investigation taxonomies offer the potential for quantifying the relationships between causal issues. Examined here are the relationships among causal factors by utilizing odds ratios and relative ri

QUANTIFYING SYSTEMIC RISK PA

(Adapted with permission from the authors' paper entitled The Use Of Odds Ratios and Relative Risk to Quantify Systemic Risk Pathways in Air Traffic Control *presented at the ISASI 2012 seminar held in Baltimore, Maryland, USA, on Aug. 28, 2012, that carried the theme "Evolution of Aviation Safety, From Reactive to Predictive." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org under the tag "ISASI 2012 Technical Papers."—Editor)*

By Michael W. Sawyer, Ph.D.; Katherine A. Berry, Ph.D.; and Edward M. Austrian, Fort Hill Group, Washington, D.C.

The Federal Aviation Administration (FAA) is currently executing a considerable transformation of the national airspace system (NAS) called Next Generation Air Transportation System (NextGen). NextGen aims to improve the convenience and dependability of air travel while increasing safety and reducing environmental impact. The introduction of new capabilities, decision-support tools, and automation through NextGen operational improvements offers the potential to change the daily activities and operations of air traffic controllers in the NextGen environment.

While NextGen may produce many positive safety improvements, the introduction of each new system and capability also offers the possibility of increasing the human contribution to risk in the NAS. From a risk management perspective, research into these effects is needed to address the potential for both positive and negative impacts on the safety of the NAS.

The ability to identify and understand human performance safety trends is necessary in complex industries, such as aviation and air traffic control (ATC). Causal factors are typically analyzed using criteria such as calendar year, domain type, geographic region, meteorological conditions, and many other conditions. Safety events, however, are seldom an outcome of one single causal factor but are more commonly the culminations of multiple, related factors. While many studies identify leading causal factors in frequency-based assessments, little has been done to examine the relationships among the various causal factors within the air traffic domain.

Risk pathways

Typically, safety incidents and accidents are not the outcome of random events but can be attributed to a combination of causal and contributing factors. Therefore, it is beneficial to the safety community to expand beyond traditional frequency-based assessments to incorporate causal factor relationship assessment. Several previous safety assessments have used a human factors framework to identify associations among key causal factors for flight deck safety, mining, and field maintenance. Within the air traffic domain, initial causal factor associations were identified by K. Berry and M. Sawyer in their work *Application of a Human Error Taxonomy for the Identification of Air Traffic Control Errors and Causal Factors.*

Our effort presented here builds on the initial associations by identifying prominent risk pathways and using quantitative risk assessments. Risk pathways identify and quantify the statistically significant relationships between causal factors for a given set of data.

In addition to identifying the leading contributing factor, the risk pathways approach identifies the significantly associated causal factors linked to the leading contributing factor. The development and implementation of mitigations strategies based only on the most frequent error types has historically proven difficult due to the variability associated with human performance. The associations determined by the risk pathways approach will assist in driving mitigations upstream. Since the higher-tier causal factors are associated with less variability, mitigation strategies targeted at these latent conditions may have the potential to produce "the greatest gains in safety benefits," according to W.C. Li and D. Harris. Establishing risk pathways will aid in driving mitigation strategies targeted toward latent conditions while still incorporating active errors.

The work presented in this article aims to show how narrative safety data can be used to quantify prominent risk pathways to permit the development of targeted mitigation strategies. To achieve this purpose, a customized air traffic safety taxonomy, AirTracs, was developed based on an analysis and synthesis of existing taxonomies including HFACS, JANUS, and HERA. The AirTracs taxonomy was then applied to examine the underlying trends present in 253 air traffic control safety events resulting in a near or actual loss of separation minima. The prominent risk pathways among the AirTracs causal factors were identified and potential mitigation strategies targeted toward those risk pathways were proposed.

ATC human factors safety taxonomy

The human factors safety community uses many safety tools and techniques to identify human performance trends in the ATC domain. However, current tools and techniques are limited in the ability to identify and describe underlying safety patterns. Over the years, many human factors accident investigation taxonomies have been developed to help identify and classify the causal factors and errors involved in near miss events, incidents, and accidents.

These taxonomies exist at many levels of detail from generalized taxonomies to domain-specific taxonomies—each with their own benefits and limitations. Generalized taxonomies, such as the Human Factors Analysis and Classification System (HFACS), are easy to understand. They

factors and errors to better understand emerging systemic sk measures to establish risk pathways.

THWAYS IN AIR TRAFFIC CONTROL

allow for trend analysis of broad causal factors but can be limited in identifying domain-specific mitigation strategies. Domain-specific taxonomies, such as JANUS and Human Error ATM (HERA), may more accurately describe individual ATC events but can have too many causal factors to provide meaningful systemic analysis.

In order to examine and quantify risk pathways, a comprehensive taxonomy is needed to ensure that the operator actions and causal factors that contribute to safety events in the NAS can be identified. Such a taxonomy would allow a safety professional to identify prominent risk pathways and to extend identification beyond frequency-based human error assessments. The Air Traffic Analysis and Classification System (AirTracs) was developed to systemically and thoroughly examine the effect of human performance on air traffic safety events. In the following sections, we will discuss and examine details of the taxonomies serving as the foundation for AirTracs.

The Human Factors Analysis and Classification System

Fulfilling a need for a standardized accident investigation taxonomy, the HFACS taxonomy was modeled on Reason's Swiss cheese model of active failures and latent conditions. Initially designed for aviation, the HFACS taxonomy consists of one tier of active errors—unsafe acts—and three tiers of latent conditions—preconditions for unsafe acts, unsafe supervision, and organizational influence. The taxonomy provides a structured, systemic approach for investigating both accidents and near miss incidents.

Due to its origins, the HFACS taxonomy has been applied to the many facets of the aviation industry. Additionally, its application has extended beyond the aviation industry to include maintenance, mining, and rail. While the HFACS taxonomy has been applied to a wide range of industries, the level of detail needed to classify domain-specific causal factors is not present within that taxonomy and similar generalized taxonomies. Without detailed information on the various causal factors, the mitigation strategies developed from generalized findings may lack the information needed for comprehensive and in-depth application.

HERA–JANUS

Developed jointly by the FAA and EUROCONTROL, the HERA-JANUS technique was created to comprehensively examine the human factors causal factors associated with safety events specifically in ATC. The HERA-JANUS taxonomy categorizes unsafe acts through detailing the error—in terms of error type, error detail, error mechanism, and information processing level. The taxonomy also details the context of the error, in terms of task, information and equipment, and contextual conditions. The HERA-JANUS taxonomy provides a thorough and meticulous approach for investigating ATC safety events. But while the taxonomy has the level of detail necessary for an exhaustive understanding of a single safety event, the technique lacks the ability to identify systemic safety patterns. Without the ability to identify emerging trends in safety data, safety practitioners will lack the ability to develop mitigation strategies that address systemic issues.

AirTracs

The Air Traffic Analysis and Classification System (AirTracs) was developed by merging the HFACS and HERA-JANUS taxonomies to accommodate the strengths of each while addressing their weaknesses. The AirTracs causal factor model framework is based on the Department of Defense (DOD) HFACS model; the detailed causal factor categories incorporate factors from HERA-JANUS. The AirTracs framework promotes the identification of human factors causal trends by allowing factors ranging from immediate operator

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__Katherine Berry__, a founding partner and human factors engineer for the Fort Hill Group, supports a variety of projects for the FAA focused on improving human performance and safety in both current operations and the NextGen environment. Previously, she conducted work in examining human factors safety issues for Air Canada, GE Energy, and GE Corporate. Katie holds a Ph.D. in industrial engineering from Clemson University.

__Edward M. Austrian__ is a Fort Hill Group NextGen systems engineer. He has experience in supporting the FAA's Air Traffic Organization in En Route and Oceanic Program Operations and the NextGen Human Factors Division. Edward was a certified flight instructor at the Daytona Beach campus of Embry-Riddle Aeronautical University. He holds a bachelor of science degree in aeronautical science and a minor in aviation safety.

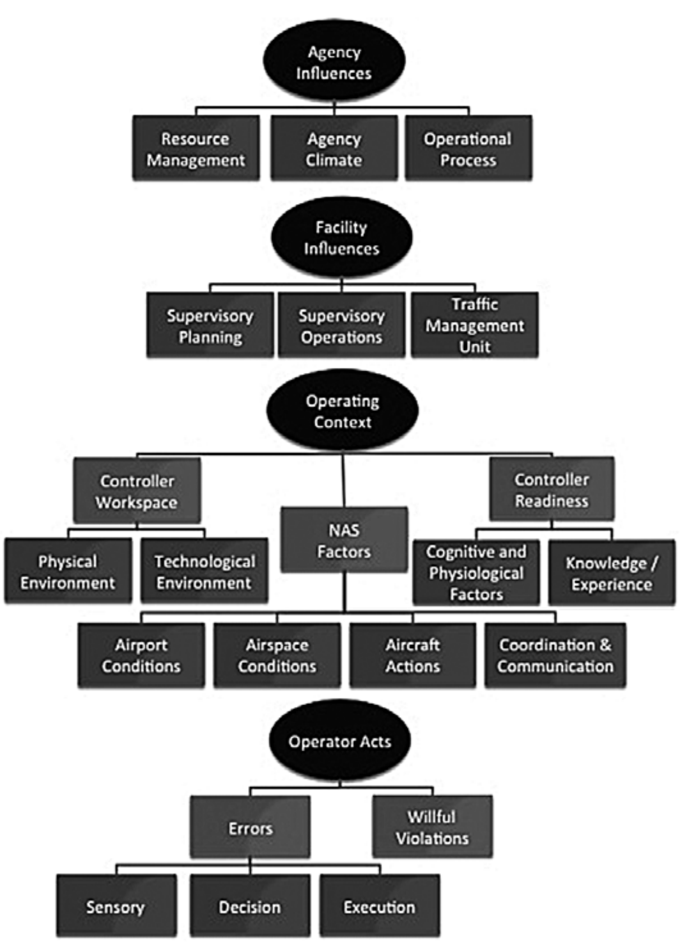


Figure 1. The Air Traffic Analysis and Classification System (AirTracs)

context to agency-wide influences to be traced to individual events while still being able to identify human factors patterns and trends. The AirTracs causal factor model can be found in Figure 1.

For safety events classified with the AirTracs framework, the presence or absence of each AirTracs causal factor at all four levels should be examined. The AirTracs causal factors are not mutually exclusive, and safety event classifications should include causal factors from all four tiers. For example, an individual safety event can include an execution error, a sensory error, cognitive and physiological factor, supervisory operations, and operational process.

AirTracs application

NASA's Aviation Safety Reporting System (ASRS) data were used for this analysis. The ASRS is comprised of voluntarily submitted aviation safety reports filed by pilots, controllers, or other NAS actors. ASRS combines the advantages of direct input on safety concerns from frontline personnel with the disadvantages of potentially biased points of view being described.

For this study, all ASRS safety incidents reported by air traffic controllers during 2011 were queried. However, only the 253 safety reports that included either a near loss or actual loss of separation minima were analyzed. These reports were classified with AirTracs using the consensus method, which required a panel's consensus on the causal factors contributing to the report. The panel members included human factors experts, retired air traffic controllers, and flight deck experts.

Statistical analysis

Each ASRS report was evaluated across all four tiers of the AirTracs framework. The presence or absence of each AirTracs causal factor was recorded for each report. An important note: The AirTracs categories are not mutually exclusive. For example, an individual report can include both an execution error and a decision error. For each AirTracs causal factor, we determined that the percentage of ASRS reports that included at least one instance of the causal factor.

In order to identify risk pathways, associations among causal factors were measured. Starting at the highest AirTracs tier, Agency Influences, the relationship between each causal factor at the higher tier and the various causal factors at lower tiers was examined using a Pearson's Chi-Square test to measure the statistical strength of the association. In the instances where the assumptions of the Chi-Square test were not met, a Fisher's Exact test was conducted (Sheskin, 2011).

If the AirTracs category resulted in a significant association being identified through the Pearson's Chi-Square test or Fisher's Exact test ($p<0.05$), the odd's ratio and relative risk values were calculated for that particular association. The odd's ratio is a measure of the degree of the association strength that compares the odds of the presence of causal factors. The relative risk value further evaluates the association strength by examining the likelihood of a high-tier causal factor being present or absent when a lower-tier causal factor is present.

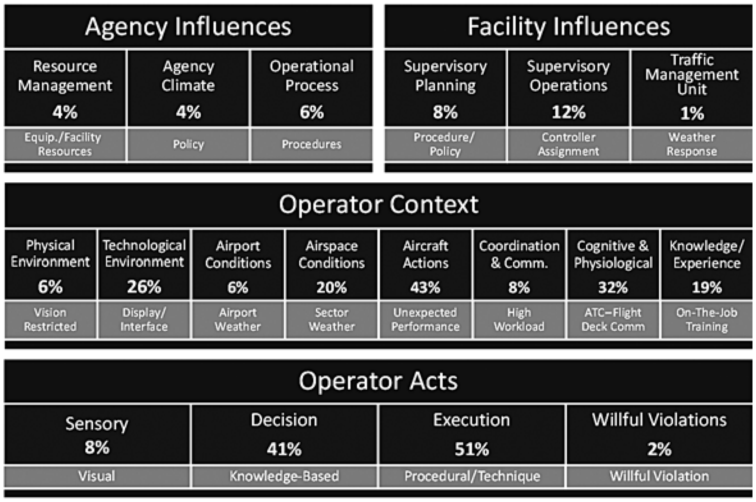
Results and discussion

The findings from the AirTracs analysis of 253 ASRS reports can be viewed in Table 1. The percentages in Table 1 do not sum to 100% since reports typically are associated with more than one causal factor. Along with the percentage of reports containing a particular causal factor, the leading subcategory for each causal factor is identified. For example, 51% of reports contain an execution error with the leading execution error being a procedural/technique error.

Operator Acts were cited in 79% of the reports examined. The leading causal factor within Operator Acts was execution error, which was cited at least once in 51% of the reports. In these reports, the controller adequately identified the issue present and developed a plan to rectify the issue but failed to adequately execute the plan to correct the issue.

The leading category within execution errors was procedural/technique error, indicating the technique or the procedure utilized by the controller was not accurately completed. In addition to execution errors, decision errors were present in 41% of the reports, with knowledge-based error being the leading category. This finding indicates controllers are developing

Table 1



Agency Influences

Resource Management	Agency Climate	Operational Process
4%	4%	6%
Equip./Facility Resources	Policy	Procedures

Facility Influences

Supervisory Planning	Supervisory Operations	Traffic Management Unit
8%	12%	1%
Procedure/ Policy	Controller Assignment	Weather Response

Operator Context

Physical Environment	Technological Environment	Airport Conditions	Airspace Conditions	Aircraft Actions	Coordination & Comm.	Cognitive & Physiological	Knowledge/ Experience
6%	26%	6%	20%	43%	8%	32%	19%
Vision Restricted	Display/ Interface	Airport Weather	Sector Weather	Unexpected Performance	High Workload	ATC–Flight Deck Comm	On-The-Job Training

Operator Acts

Sensory	Decision	Execution	Willful Violations
8%	41%	51%	2%
Visual	Knowledge-Based	Procedural/Technique	Willful Violation

plans based on faulty information. The high percentage of reports with both execution and decision errors is consistent with previously completed studies of ATC, aviation, and other industries. However, the identified frequency of execution and decision errors present more questions than answers, and the development of meaningful mitigation strategies for these findings is difficult. Therefore, it is important to extend the analysis to develop a more comprehensive view of risks present in the NAS.

Risk pathways

The AirTracs risk pathways where statistically significant associations between causal factors were found are shown in Table 2. Only those causal factor pairings that were found significant from the Chi-Square analysis ($p<0.05$) were reported. The relative risk values indicate the likelihood of a high-tier causal factor being present or absent in a report when a lower-tier causal factor is present. For example, the findings for the resource management–supervisory planning pairing can be interpreted to show that a report citing a resource management causal factor is 4.784 times more likely to also have a supervisory planning causal factor than a report without a resource management causal factor.

Table 2: AirTracs Risk Pathways

AirTracs Causal Categories	Pearson's Chi-Square Value	Significance	Odds Ratio	Relative Risk
AirTracs Tier 4—Agency Influences				
Resource Management X Supervisory Planning	8.288	**	6.676	4.784
Resource Management X Technological Environment	4.360	*	3.833	2.259
Resource Management X Airport Conditions	11.491	***	8.885	6.256
Agency Climate X Knowledge/Experience	5.011	*	3.750	2.500
Operational Process X Airspace Conditions	4.118	*	2.939	2.164
AirTracs Tier 3—Facility Influences				
Supervisory Planning X Technological Environment	9.771	**	4.051	2.373
Supervisory Operations X Airspace Conditions	7.998	**	3.058	2.261
Traffic Management X Airspace Conditions	4.212	*	8.417	3.472
AirTracs Tier 2—Operating Context				
Physical Environment X Sensory Error	16.973	***	8.929	6.097
Physical Environment X Decision Error	4.288	*	4.391	0.338
Technological Environment X Sensory Error	11.159	***	4.583	3.977
Cognitive and Physiological X Execution Error	6.395	*	2.001	1.371
Knowledge/Experience X Decision Error	5.214	*	2.067	1.479
Airport Condition X Willful Violation	13.087	***	16.786	14.813
Aircraft Action X Sensory Error	6.409	*	4.493	0.244
Aircraft Action X Decision Error	5.140	*	1.812	0.699
Aircraft Action X Execution Error	4.676	*	1.736	0.761

*$p < 0.05$, **$p<0.01$, ***$p<0.001$*

From the assessment, 17 significant causal factor relationships emerged. Of note are the relationships between the Aircraft Actions factor and each of the three error causal factors. All three relationships produced significant results with relative risk values less than one (e.g., a report with an Aircraft Action causal factor was 0.244 times as likely to have a Sensory Error as a report without an Aircraft Action.).

These reports represent situations where the controller was able to successfully manage and respond to aircraft actions with unsafe consequences. For these reports, the successful actions of the controller should be more thoroughly examined to determine if best practice guidelines could be created for handling aircraft actions. Linking together these relationships based on common factors allows for prominent risk pathways to be identified and to show the systemwide effects of causal factors. Five of the most prominent risk pathways along with their implications and potential mitigation strategies are discussed below.

Agency Climate Pathway

The Agency Climate Pathway demonstrates how agency-wide issues can be connected to specific operator actions. Agency Climate refers to the environment, policy, and culture throughout the agency that contribute to adverse events. Sample categories within Agency Climate include safety culture, labor relations, and agency policies. In this pathway, shown in Figure 2, Agency Climate shows a significant association with the Knowledge/Experience factor, which in turn is associated with Decision Errors.

Reports citing Agency Climate as a causal factor were 2.5 times more likely to have a Knowledge/Experience causal factor than reports that did not identify

Figure 2. Agency Climate Pathway with relative risk values

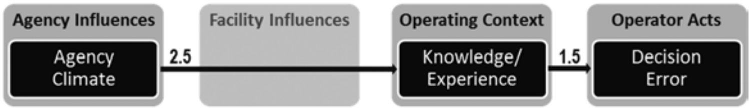
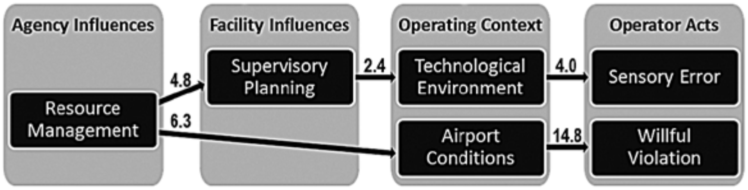


Figure 3: Resource Management Pathway with relative risk values



an Agency Climate causal factor. Knowledge/Experience as a causal factor refers to situations when controllers lack the knowledge or experience to successfully execute a task, policy, or procedure. Sample categories within Knowledge/Experience include developmental controller, low experience controller, or unfamiliar task or procedure.

The association between Agency Climate and Knowledge/Experience suggests that Agency Climate factors, such as inadequate training or staffing policies, are creating an environment where some controllers do not have adequate training or experience necessary to prevent losses of minimum separation standards.

The effect of this Knowledge/Experience gap is associated with Decision Errors. Reports citing Knowledge/Experience as a factor were 1.48 times more likely to also identify a Decision Error than reports without a Knowledge/Experience causal factor. Decision Errors occur when the controller has the adequate sensory information but determines an inadequate or inappropriate plan of action to handle the situation at hand. This Knowledge/Experience–Decision Error relationship suggests that the knowledge or experience level of a controller is potentially related to the development of an inadequate plan or making an insufficient choice leading to a near or actual loss of separation minima.

Several key implications can be drawn from this pathway. First, it shows a distinct and quantified pathway from Agency Influences to Operator Acts. The policies and training resources being made available to controllers effect their abilities to make correct and safe decisions regarding the traffic in their sector.

Second, by establishing this pathway further investigation can be focused directly on this relationship in order to develop targeted mitigation strategies. The top-identified category within Knowledge/Experience was On-the-Job-Training (OJTI), suggesting OJTI as the primary issue present. ATC relies heavily on OJTI, which allows a trainee controller to actively control traffic while being supervised by a certified professional controller (CPC). The OJTI experience allows for trainee controllers to learn the nuances of the job and in some instances to learn from their mistakes. While a CPC supervises all actions and has the capability to take over control from the trainee, the trainee's actions do occasionally lead to negative outcomes, such as a near or actual loss of separation minima.

The identification of causal factor pathways allows for directed mitigations to target specifically the causal factors that are associated with the operator acts and, in turn, the adverse outcomes. In such a case, the role that Agency Climate plays in providing controllers the information they need to make decisions suggests that perhaps policies regarding OJTI should be investigated. Further investigation into this issue could identify the specific types of information and scenarios that controllers are not currently receiving. This would allow training to be focused on the specific issues being seen in NAS operations.

Resource Management Pathway

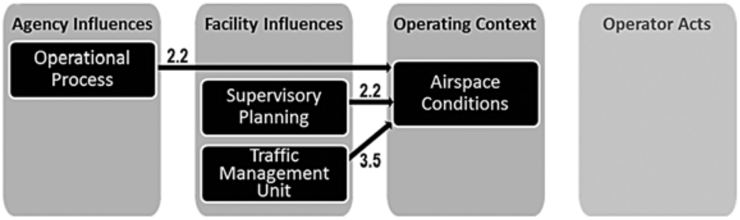
The Resource Management Pathway in Figure 3 shows how the effects of poor resource management propagate through the NAS and ultimately contribute to safety events. Resource Management describes the agency-level apportionment and maintenance of equipment, facilities, human resources, and budget resources. The Resource Management Pathway is composed of two branches, one leading to Sensory Errors and the other leading Willful Violations.

Sensory Error Branch—The first branch of the Resource Management Pathway shows a significant association between Resource Management and Supervisory Planning. A report involving Resource Management was 4.784 times more likely to cite Supervisory Planning than a report without a Resource Management causal factor. Sample categories within Supervisory Planning include planned staffing levels, facility equipment maintenance, and training of controllers, suggesting that agency decisions have a direct effect on a supervisor's ability to manage an area.

This pathway continues with the Supervisory Planning–Technological Environment connection. Reports citing Supervisory Planning were 2.38 times more likely to also cite Technological Environment than was a report without Supervisory Planning causal factors. The Technological Environment causal factor describes the technical workstations, systems, and automation a controller must interact with. This relationship suggests that the technological issues that are present in these safety events are not isolated occurrences but rather are connected to facility-level influences, which are in turn associated with agency-level decisions. This could either be the result of failing to fix malfunctioning or inoperable technological systems or of not providing effective and reliable technological systems to controllers.

The issues identified with the Technological Environment causal factor are also associated with weaknesses related to Sensory Errors. A report citing Technological Environment was 3.98 times more likely to have a Sensory Error than a report without a Technological Environ-

Figure 4. Airspace Conditions Pathway with relative risk values



ment causal factor. Sensory Errors occur when the controller acts or fails to act based on a misinterpretation of auditory, visual, or other sensory information. This relationship suggests that Technological Environment issues present are related to the means in which information is visually displayed or aurally relayed to the controller, rather than related to the type of or quality of information being relayed.

This sensory branch of the Resource Management Pathway emphasizes the importance of providing the various resources necessary to design, update, and maintain the automated systems that controllers use to control traffic. Further, when technological issues are identified there should be a mechanism in place to allow these technological issues to be communicated to facility- and agency-level stakeholders. Therefore, it is essential that the agency and the facility allocate resources for technical operations to maintain the systems.

Willful Violation Branch—The second branch of the Resource Management Pathway highlights the relationship between Resource Management, Airport Conditions, and Willful Violations. A report with a Resource Management causal factor was 6.256 times more likely to also have an Airport Conditions causal factor than a report without a Resource Management causal factor. An Airport Conditions causal factor describes the environmental and design conditions of an airport, and sample causal categories include airport weather, airport configuration, and ground vehicle traffic. The relationship between Resource Management and Airport Conditions demonstrate that the agency-level decisions regarding equipment, human, and monetary resources has the ability to effect the adverse conditions at an airport.

This branch continues with Airport Conditions being associated with Willful Violations. A report with an Airport Conditions causal factor was 14.813 times more likely to have a Willful Violation causal factor than a report without an Airport Conditions causal factor. Willful Violations occur only when an operator willfully and knowingly disregards the rules, regulations, policies, and standard operating procedures. It is important to note that while only 2% of the reports contained a Willful Violation, those reports were overwhelmingly related to Airport Conditions. This relationship suggests that the violations that do occur are not the result of intentional neglect or recklessness but rather happen as controllers push beyond the boundaries of normal operations in order to cope with degraded or inadequate airport conditions. Violations are still quite serious occurrences that warrant individual investigation to determine the true reasons for violating allowable procedures and to develop mitigations accordingly.

Airspace Conditions Pathway

The Airspace Conditions Pathway in Figure 4 shows the Agency and Facility issues significantly associated with the Airspace Conditions causal factor. The Airspace Condition causal factor refers to the environmental and design conditions of the airspace where the near or actual loss of separation minima occurred.

The Airspace Conditions causal factor includes the causal categories such as sector design, combined sectors, and sector overload/traffic. Three other causal factors were shown to be significantly associated with Airspace Conditions: Operational Process, Supervisory Planning, and Traffic Management Unit.

Of the three associated causal factors, Traffic Management Unit showed the highest relative risk rating as reports citing Traffic Management Unit were 3.47 times more likely to also identify Airspace Conditions than reports that did not cite Traffic Management Unit. The Traffic Management Unit causal factor described the actions and operations of the Traffic Management Unit, such as issuance of traffic management initiatives and development of weather response plans.

While the Traffic Management Unit does not directly interact with individual aircraft, their actions are directly related to the airspace conditions in which controllers must manage traffic. Inadequate traffic management plans have the potential to increase a controller's workload by too many aircraft being routed through a sector or by a controller having to issue multiple weather-related reroutes and amendments.

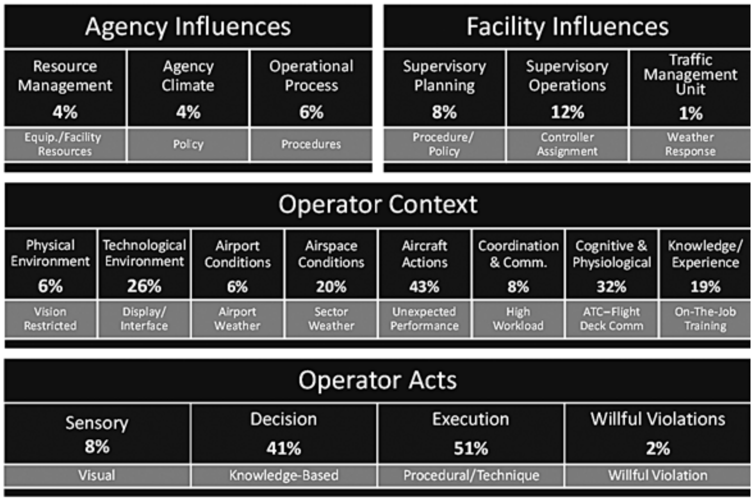
Furthermore, a report with an Operational Process causal factor was 2.164 times more likely to have an Airspace Condition causal factor than a report without an Operational Process causal factor. The Operational Process causal factor describes the various agency-level operations, processes, and oversight. Many of the reports citing both of these causal factors represented situations where either the sector design or policies related to handoff procedures created the opportunity for adverse airspace conditions, which later contributed to the adverse outcome of a near or actual loss of separation minima.

Additionally, a report with a Supervisory Operations causal factor was 2.261 times more likely to have an Airspace Condition causal factor than a report without one. The Supervisor Operations causal factor refers to the day-to-day operations and tasks conducted by facility management. This relationship infers that the daily actions of the supervisor or frontline manager can potentially effect the airspace and traffic within the airspace. In particular, the frontline manager determines when and how both sector and controller positions should be combined and uncombined. If a frontline manager waits too long to split apart combined sectors, the controller could inadvertently become overloaded, thereby increasing the potential of an adverse event and making the sector split more difficult.

The lack of any significant associa-

Figure 5: Cognitive and Physiological Pathway with relative risk value

Figure 6: Physical Environment Pathway with relative risk values



Agency Influences

Resource Management	Agency Climate	Operational Process
4%	4%	6%
Equip./Facility Resources	Policy	Procedures

Facility Influences

Supervisory Planning	Supervisory Operations	Traffic Management Unit
8%	12%	1%
Procedure/Policy	Controller Assignment	Weather Response

Operator Context

Physical Environment	Technological Environment	Airport Conditions	Airspace Conditions	Aircraft Actions	Coordination & Comm.	Cognitive & Physiological	Knowledge/Experience
6%	26%	6%	20%	43%	8%	32%	19%
Vision Restricted	Display/Interface	Airport Weather	Sector Weather	Unexpected Performance	High Workload	ATC–Flight Deck Comm	On-The-Job Training

Operator Acts

Sensory	Decision	Execution	Willful Violations
8%	41%	51%	2%
Visual	Knowledge-Based	Procedural/Technique	Willful Violation

tion between the Airspace Conditions causal factor and the causal factors at the Operator Act tier suggest the Airspace Conditions causal factor is linked to various stages of the decision-making process rather than one particular stage. The Operator Act tier is modeled after the decision-making process where information must first be accurately perceived (Sensory Error), a decision or response must be developed (Decision Error), and the response must be properly executed (Execution Error).

In other pathways, higher-tier causal factors were associated with particular Operator Acts causal factors. However, this pathway lacks any direct association with these causal factors, indicating that airspace conditions potentially affect all stages of the decision-making process. Mitigation strategies targeted toward this pathway should incorporate all the stages of the decision-making process and should not be limited to a singular stage or causal factor.

Cognitive and Physiological Factors Pathway

The Cognitive and Physiological Factors Pathway shown in Figure 5 is composed of a single, but important, connection between Cognitive and Physiological factors and Execution Errors.

The Cognitive and Physiological factor refers to the mental and physical condition of the controller and includes sample causal categories such as expectation bias, automation reliance, and fatigue. A report with a Cognitive and Physiological factor was 1.37 times more likely to have an Execution Error than a report without one. Execution Errors describe situations where a controller has correctly perceived the situation and determined the proper course of action but makes an error while executing the plan. Sample Execution Error categories include memory errors and inadvertent operations.

The Cognitive and Physiological Factor–Execution Error relationship suggests that the mental and physical state of the controller primarily effects a controller's ability to properly execute his or her plans. In many reports, controllers described how the effect of factors such as fatigue or stress from high workload inhibited their ability to complete a routine task. This relationship also provides a key insight into potentially reducing executions errors by focusing mitigations at reducing the prominent causes of the identified Cognitive and Physiological factors.

Physical Environment Pathway

The Physical Environment Pathway, Figure 6, traces the effects that a controller's immediate workspace can have on his or her performance. Sample Physical Environment causal categories include restricted vision, lighting, and workspace clutter. Physical Environment was found to have significant relationships with Sensory Errors and Decision Errors.

A report with a Physical Environment causal factor was 6.10 times more likely to have a Sensory Error causal factor than a report without one. This suggests that when a controller's workspace is inadequate the controller may have difficulty gathering the necessary sensory information in order to safely control traffic. By contrast, a report with a Physical Environment causal factor was 0.34 times as likely to have a Decision Error causal factor as a report without one.

These relationships suggest that Physical Environment causal factors affect the earlier stages of a controller's decision-making process. The adverse effects occur during the sensory or perception stages of decision-making rather than the decision selection stages. The most prevalent Physical Environment factors should thus be assessed, as sensory information is a controller's first line of defense for identifying and preventing adverse outcomes.

Conclusion

In order to examine the dynamic relationships of causal factors, an expansive human factors taxonomy, AirTracs, was developed to permit safety professional to identify prominent risk pathways. The AirTracs taxonomy, which is a combination of two key human factors taxonomies, HFACS and HERA-JANUS, was used in assessing 253 ASRS air traffic control reports. The percentage of reports linked to each causal factor was identified, in addition to the leading causal category for each causal factor. Five key risk pathways were identified and potential mitigation strategies were discussed.

Targeting systemic mitigation strategies offers the potential to proactively reduce risks associated with the causal factors within the pathway. Furthermore, while this methodology was applied to the air traffic domain, the approach could be extended to the flight deck domain and any other high-risk, human-centric domain. ◆

ISASI's Kapustin Scholarships Awarded

The ISASI Rudolf Kapustin Memorial Scholarship program has again selected four students to receive its benefits.

By Esperison Martinez, Editor

Richard Stone and Ron Schleede, co-chairs of the ISASI Rudolf Kapustin Memorial Scholarship program, noted that generous membership contributions have enabled the program to again select four well-qualified students to receive ISASI's annual $2,000 scholarship. Awardees are Mackenzie Dickson, Embry-Riddle Aeronautical University, U.S.A.; Lauren Sperlak, Purdue University, U.S.A.; Jason Goodman, Embry-Riddle Aeronautical University, U.S.A.; and Camille Burban, Cranfield University, UK.

The Kapustin fund was established in 2002 to memorialize all deceased ISASI members. It was named in honor of the former ISASI Mid-Atlantic Regional Chapter president, Rudy Kapustin. He died in 2002, and throughout his long career he was always a strong safety advocate.

The ISASI scholarship is intended to encourage and assist college-level students interested in the field of aviation safety and aircraft occurrence investigation, according to Stone. Contributions have provided and will continue to provide an annual allocation of funds for the scholarship. Contributions are tax-deductible in the U.S. and may be made in the name of a specific deceased member payable to the ISASI Kapustin fund and sent to the ISASI home office.

Twenty-nine worthy students have now received assistance. What began as two scholarship awards has now grown to four. The requirements are that applicants must be enrolled as full-time students in an ISASI-recognized education program, which includes courses in aircraft engineering and/or operations, aviation psychology, aviation safety and/or aircraft occurrence investigation, etc., with major or minor subjects that focus on aviation safety/investigation.

An award of US$2,000 is made to each student who wins the competitive writing requirement, meets the application requirements, and who registers to attend the ISASI annual seminar. The award will be used to cover costs for the seminar registration fees, travel, and lodging/meals expenses. Any expenses above and beyond the amount of the award will be borne by the recipient. ISASI corporate members are encouraged to donate "in kind" services for travel or lodging expenses to assist student scholarship recipients.

Application and scholarship availability notices are posted in some 50 colleges and universities worldwide. You are encouraged to promote this scholarship to individuals, student groups, parents, and applicable departments of your alma mater. You are also encouraged to assist in securing and completing applications for any appropriate student(s).

The deadline for applications is April 15 of each year. Full application details and forms are available on the ISASI website, www.isasi.org.

MACKENZIE (MACK) DICKSON, 22, is currently a senior at Embry-Riddle Aeronautical University, Daytona Beach, Florida, seeking a B.S. in aeronautics with minors in aviation safety and business administration. A cadet in ERAU's Air Force ROTC Detachment 157, he will commission as a second lieutenant in the U.S. Air Force upon graduation in December. In February 2013, he was selected to attend U.S. Air Force pilot training upon commissioning. He has been interested in aviation since a young age, taking his first flight at the age of 12. His interest in aviation safety was born out of his interest in aviation. ERAU's safety education has built upon this interest to allow him to potentially seek an aviation safety career in the future. This summer, Dickson will have the opportunity to gain real-world aviation safety experience by working for JetBlue's Aviation Safety Department as an intern. About his selection he said, "I am extremely thankful for the opportunity that ISASI has given me through this scholarship. I am very much looking forward to Vancouver!"

His winning essay follows:

SHIFTING THE SAFETY PARADIGM: THE CHALLENGE OF MILITARY AIR SAFETY INVESTIGATORS

By Mackenzie (Mack) Dickson

The aviation industry has spent decades evolving the concept of "safety" from a reactive investigative practice to a proactive, culturally driven paradigm. Though civilian airlines have adopted programs that seek to identify hazards inherent in their operations to prevent future mishaps, the U.S. military's approach to aviation safety is still in a state of transformation. Proactive safety programs are becoming the norm for the U.S. military, but instilling a culture of safety in everyday operations is the prime motivation behind the work of safety professionals throughout the Department of Defense (DOD).

The findings from mishap investigations will continue to allow the military to expand its aviation safety programs by identifying known causal factors and preventing error chains from leading to future mishaps. Though the military has taken active steps in making safety more proactive than reactive, a measurable decrease in mishaps must be recorded to recognize the success of these programs. According to the Air Force Safety Center, the decrease in mishaps has leveled off (Cowsert, 2012). The challenge for military air safety investigators lies in establishing a successful fusion between reactive safety investigations and everyday proactive safety programs while utilizing those programs to promote a proactive safety paradigm shift.

The first step in changing the safety paradigm is recognizing the positive impact that safe operations have on combat readiness. According to Air Force Chief of Safety Maj. Gen. Margaret H. Woodward, "It is absolutely essential that safety is embraced as a core value in preserving combat capability" (Cowsert, 2012). Military air safety is not just about saving lives and money, its purpose is to protect our national defense assets from mishaps that may take them away from their chief purpose of protecting the nation. The proactive safety culture is appropriate for operations in the military because the stakes are extremely high. The following aspects of military flight operations define the challenges that military air safety investigators face in learning from mishaps and establishing proactive safety measures.

First, all military flight operations must be seen and treated as high risk at all levels of military leadership. The military is exceptional at recognizing threats from enemy assets and using tactics and technology to defeat those threats, but what about flight operations in which our weapons systems and aircrews are thousands of miles away from enemy threats? The very nature of military flight operations, whether they are in theater or not, makes them inherently dangerous. High speeds, close formations, aerial refueling, and physiologically demanding flight maneuvers are just some of the aspects that separate military flying apart from that in the civilian world.

Second, the unique culture of the military should be taken into account in the safety paradigm shift. The civilian world is vastly different from the military in multiple ways, but there are specific differences that affect military aviation. Military units are focused on completing tasks with limited resources at a high operations tempo. Naturally, safety may not result as the top priority. Safety must not be viewed as just following checklists and procedures, but must be a mindset that reflects the idea that assets must be kept combat-ready through safe practices. The thousands of hours that aircrews train to prepare for the hundreds of hours of combat they will face means that the exposure of aircrews and assets to noncombat-related hazards is high. Whatever the mission, safety must be seen as the top priority that keeps our military aircrews and assets ready to fight the nation's battles.

Third, the flight experience of military aircrews affects the safe operation of military assets. Aircrews are placed in state-of-the-art aircraft with relatively little experience. On average, military pilots will have approximately 200 hours of formal military flight training before starting to fly their specific aircraft ("Pilot Training," 2012). This is compared to the minimum 1,500 hours mandated by Congress for airline pilots (Pasztor & Nicas, 2012). Military aircrews undergo months of rigorous training to earn their wings. There is no doubt that the people entrusted with some of the military's most advanced weaponry are qualified to operate that weaponry. The issue lies with the indoctrination of these aircrews into a culture of safe operation. Military air safety professionals face the challenge of not only maintaining proactive safety programs with aircrews that have entered active service, but also injecting proactive safety into the training of military aircrews.

Recognizing the unique nature of military flight operations is just one step in ensuring that the future of military air safety is defined by a proactive safety focus. Since safety is essential for ensuring combat readiness, safety education and training must be utilized at all levels of the chain of command. Additionally, the increasing prevalence of joint operations justifies the creation of inter-service safety programs. Currently, each branch relies on safety programs sent down from their respective safety centers to define their practices and methodologies. Organizational challenges exist for military air safety investigators to implement their programs across the DOD. Perhaps the future of the military organizational structure will allow for the creation of a "joint safety center" fully dedicated to promoting a proactive safety culture DOD-wide.

Lastly, military air safety investigators face the challenge of ensuring the posterity of the paradigm shift they are trying to instill. Training future air safety investigators to not only investigate mishaps, but to also encourage the proactive safety mentality is essential in ensuring that proactive safety survives well into the future. Safety in the military has evolved from "active" to "reactive" to "proactive" and "predictive." (Cortés, 2011) An emphasis on training the next generation of military air safety investigators will eventually lead to the eradication of a reactive safety mindset. Not only training future safety professionals, but also spreading trained, safety-minded individuals throughout the military's flying units are important in changing the military safety paradigm.

The definition of air safety, as it pertains to the military, is constantly evolving. Using known hazards identified from previous mishaps is no longer acceptable in establishing comprehensive safety programs in the U.S. military. Proactive safety programs are part of the equation that is defining the military air safety transformation. Military air safety investigators face cultural and organizational challenges in their efforts to fundamentally change air safety in the military. Recognizing the unique, yet risky, nature of military flight operations while promoting a cultural paradigm shift toward proactive safety will result in the total transformation that military air safety professionals are seeking.

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LAUREN SPERLAK, 26, currently a technology candidate at Purdue University, West Lafayette, Indiana. Expecting to complete her studies in 2015, she holds an undergraduate degree in professional flight technology with minors in aircraft turbine-engine and reciprocating-engine technology. Sperlak also holds an FAA commercial pilot certificate with instrument and multi-engine ratings and an FAA airframe and powerplant certificate. Her professional aspirations are to become a professor at an aviation university or to take a position in safety management or maintenance management in the aviation industry. Asked how her interest in aviation came about, she said: "I originally became involved with aviation safety when I was researching topics for my dissertation. I have always been passionate about aviation and ways to improve the industry. I have taken several courses pertaining to aviation safety, culture, and operational improvement, which have led me to my ultimate decision to investigate proactive approaches to safety systems in aviation maintenance. It is my hope through this scholarship to learn more about accident investigation, the root causes of accidents, and how to prevent them in the future.”

Her winning essay follows:

THE CHALLENGES OF AIR SAFETY INVESTIGATORS

By Lauren Sperlak

Photo not available

Investigating the cause or causes of an aircraft accident is a tedious and time-intensive process that should be done with vigor and care. To accurately determine the true cause, the accident investigation could take years even though there is pressure from the press, the families, the companies, and possibly others who are anxious for the report. The investigator must extract information from multiple sources in an effort to recreate as much of the flight as possible as accurately as possible. The compilation and assimilation of data pertaining to the accident require expertise in a variety of areas in aviation operations to properly piece together the events leading to the accident. However, every accident reveals improvements that need to be made. Reporting and sharing these findings can help reduce similar high-risk activities that have led to an accident. Air safety investigators are the catalysts of safety reforms within the industry as a result of accidents and the findings from those accidents made by the investigators.

Commercial airline travel is one of the safest modes of transportation with a relatively low accident rate. However, fatal accidents, particularly of a commercial airliner, are highly publicized and have the potential for a large death toll in a single accident. Air investigators must ensure that their final reports that identify the causal factor or factors of the accident are conclusively accurate. According to Wood and Sweginnis (2006), the final selection of findings, causes, and recommendations creates the most controversy. Accidents involve numerous parties that all have a stake in the findings. In the wake of an accident, the governing body responsible for creating and enforcing regulations typically recommends actions for the entire industry, not just the companies involved in the accident.

The isolation of a single causal factor of an accident is extremely difficult. Accidents generally occur due to a series or culmination of events. However, classifications of certain findings and whether or not these findings should be included in the report and listed as a causal factor have been a topic of discussion by air safety investigators. The National Transportation Safety Board (NTSB) insists on using a single statement of probable cause despite having the ability to attribute an accident to multiple causes. The International Society of Air Safety Investigators (ISASI) has recommended to the International Civil Aviation Organization (ICAO) to include both descriptive causes (what happened) and explanatory causes (why it happened) in their reports (Wood & Sweginnis, 2006). Unfortunately, the recommended separation of causes into descriptive and explanatory has yet to be adopted. Australia has adopted the practice of determining significant factors to avoid the term causes and allows for more than one factor to be listed as the reason an accident occurred and does not insist on the isolation of a single factor (Wood & Sweginnis, 2006). This inconsistency of report requirements creates issues among air safety investigators.

The identification of causal factors is not only important to those affected, but it is also important to the global aviation industry as it moves forward. “Much of the success in air traffic safety has been due to the knowledge gained from prior aircraft accident investigations carried out with the aim of ensuring that accidents in similar circumstances will never recur” (Milosovski, Bil, & Simon, 2009, 10). Unfortunately, accident investigators, despite all the advancements in technology and their extensive experience, sometimes cannot determine the causal factors associated with an aircraft accident. The sheer amount of data, especially in a transport-category aircraft accident, that is involved after an accident occurs can be challenging to decipher or comprehend. Teams of investigators under one investigator, the Investigator-in-Charge (IIC), are assigned with collecting pertinent information from their assigned area before being brought together as a group to determine what exactly happened (ICAO, 2000).

The investigation of an accident, some think, should be conducted similar to conducting a research study. This approach requires creating research strategies to help answer questions that arise after an accident (Milosovski, Bil, & Simon, 2009). Like any good researcher, the investigators must remove themselves from bias or preconceived notions on the reasons an event happened and rely on what the facts conclude. There will always be opposition and outside pressures during an investigation due to political agendas and parties associated with the accident that may be the subject of litigations or lawsuits (Lundburg, Rollenhagen, & Hollnagel, 2010; Milosovski, Bil, & Simon, 2009; Burgoyne, 1981). Investigators, despite the scrutiny of interested parties, “must be strictly objective and totally impartial and must also be perceived to be so” (ICAO, 2000, I-2-1). It is clear that the pressure placed upon investigators to conduct themselves professionally is critical to every investigation. Air safety investigators are held in high regard in the eyes of the public, and this level of trust requires the investigator to be impartial, accurate, and objective.

As the airline industry transitions from a reactive to a proactive approach to safety and risk management, so must accident investigators. The uses of accident models and safety assessment approaches have been some of the recent topics of discussion on ways to improve accident investigation (Stoop & Dekker, 2011; Lundburg, Rollenhagen, & Hollnagel, 2010). However, no matter what direction or approach the future holds, accident investigation and the compilation of information done during an investigation should inevitably be used to improve the way the airline industry operates and handles potential high-risk situations. It is the job of the investigators to support and enforce this agenda of improvement for future travelers’ safety.

In order to prepare for the future, one must learn from the past. Air safety has relied upon an established foundation of learning from the past. To reduce future accidents, current and future industry members may learn from the identification of causal factors and the multiple other factors that resulted in accidents. As challenging as it may be for an air safety investigator to piece together the wreckage to determine the cause or causes, it ultimately helps in the prevention of similar situations to occur. Through the development and eventual use of models and approaches, air safety investigators can work to remove emotion and agenda from the investigation to subsequently determine what really happened and recommend preventative measures for the future.

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JASON J. GOODMAN, 31, a native of Brighton, Massachusetts, is currently a master of science in human factors and systems candidate at Embry-Riddle Aeronautical University (ERAU), Daytona Beach, Florida. He holds a bachelor of science in aviation flight operations. Jason took his first flight at age 12 in a Piper Tomahawk, and it set his career path. He went on to earn his commercial pilot certificate with instrument, single-engine, multiengine, and instrument ratings. A strong interest in flight safety led to an MS in safety science with a concentration in aviation safety and aircraft accident investigation. In private industry, he joined the AOPA Air Safety Foundation and helped to develop online pilot safety courses and conducted aviation human factors research at the Volpe Center (U.S. DOT). He then returned to ERAU to gain his second master's degree in human factors. At present, he is serving as a safety intern in the Safety Department at Spirit Airlines.

His winning essay follows:

THE CHALLENGES FOR AIR SAFETY INVESTIGATORS: FLIGHT RECORDERS TO LIGHTWEIGHT DATA RECORDERS

By Jason J. Goodman

When investigating an accident, air safety investigators are charged with the responsibility of determining what exactly happened, why the accident occurred, and what was learned from the mishap to prevent a similar crash in the future. Careful examination of the accident wreckage helps the investigator piece together the accident puzzle. Besides the physical evidence, the black boxes provide valuable information to unravel the story of an accident. Over the years, flight recorders have evolved from rudimentary foil recorders to tape recorders to technologically advanced solid-state recorders (L-3 Communications).

Historically, these flight data recorders (FDRs) and cockpit voice recorders (CVRs) were designed and mandated on board commercial aircraft to ensure public confidence and safety (Grossi, 1999). Unlike commercial aircraft, general aviation (GA) aircraft were not equipped with flight recorders. The need for flight recorders on board GA aircraft is now greater than ever, as the fleet has been transitioning from classic airplane designs with steams gauges to technologically advanced aircraft with sophisticated electronic displays (AOPA Air Safey Foundation, 2005). The two key challenges for air safety investigators are losing unrecorded flight data and recovering unprotected data from nonvolatile memory sources in the event of a mishap.

On Oct. 11, 2006, Cory Lidle, a private pilot, and his flight instructor were maneuvering a Cirrus Design SR20, N929CD, above the East River when the plane impacted the side of an apartment building in Manhattan. Sifting through the wreckage, air safety investigators recovered the multifunction display's memory microchip. Inevitably, the data on the chip did not survive the impact forces. The Cirrus Design SR20 was not equipped with a flight data recorder or cockpit voice recorder (National Transportation Safety Board, 2007). The lack of a flight recorder precluded the air safety investigators from listening to the pilot's cockpit communications, subtle speech changes, and voice inflections (Hersman, 2012). The absence of a flight recorder also prevented the air safety investigators from comparing available radar data to relevant aircraft performance parameters. The considerable accuracy and resolution limitations of the recorded radar data likely impacted the accident investigation, too (Grossi, 1999).

General aviation aircraft manufacturers such as Cirrus, Diamond, and Lancair have chosen to design modern aircraft with composite structures in lieu of aluminum materials. These composites are lighter, stronger, and more flexible than aluminum but leave different evidence and failure signatures (Jones, 1999). Failure patterns from composite materials without typical material signatures present challenges for air safety investigators. Concrete physical traces may not be available in the remains of a modern GA aircraft accident (Hersman, 2012). Innovative flight recorder technology and clever investigative techniques are needed to examine the accident wreckage. The recent development of lightweight data recorders will offer air safety investigators meaningful data and information to carefully examine GA accidents, especially crashes involving modern aircraft fabricated from composite materials.

On Apr. 2, 2012, an experimental amateur-built Seawind 3000, N514KT, departed Deland Municipal Airport (DED) to fly to Daytona Beach International Airport (DAB) to repair a malfunctioning transponder. Moments after takeoff, the aircraft crashed into the rooftop of a Publix supermarket about one mile from the departure end of Runway 23 at DED. The owner, a private pilot, and a commercial pilot on board the aircraft endured serious injuries. The Seawind 3000 experimental aircraft sustained substantial damage. A post-crash fire consumed a large portion of the composite airframe and completely destroyed the cockpit. Two out of three propeller blades melted or fractured. Post-impact fire damaged the engine, too (NTSB, 2012). The loss of significant evidence from both the Seawind 3000's airframe and cockpit make this mishap a challenge to investigate. The malfunctioning transponder likely prevented ATC radar from recoding the aircraft's altitude, airspeed, and heading information. A flight recorder was not required or installed on board this experimental aircraft. The lack of valuable data from a crash-survivable recorder hinders the air safety investigators from addressing basic investigative questions, reconstructing the sequence of events, and determining a probable cause or contributing factors.

L-3 communications created a lightweight data recorder (LDR) specifically designed for GA aircraft. This small LDR weighs less than five pounds. The LDR is capable of recording audio, video, flight data, and GPS data. These data are stored and protected on a crash survivable memory unit. The memory can hold up to two hours of audio, two hours of analog video, and 25 hours of flight or GPS data (L-3 Communications, 2010).

Perhaps the most practical feature of the LDR is the capability to download all recorded data directly to a personal computer. In regard to environmental protection, the flight recorder can tolerate 250 pounds of force in penetration, endure 5,000 pounds of force in static crush, withstand 1,100° C flame for 15 minutes and 260° C fire for five hours, and survive an impact shock of 1,000 G's (L-3 Communications, 2010). For maximum crash protection, the LDR must be installed in the tail section of the fuselage.

Today, a solid-state flight data recorder (SSFDR), a solid-state cockpit voice recorder (SSCVR), and a quick access recorder (QAR) are required equipment on board commercial aircraft (L-3 Communications). Unfortunately, the Federal Aviation Administration (FAA) has not mandated the installation of flight recorders on board GA aircraft. Historically, GA aircraft didn't have the capacity to record or store flight data. The physical dimensions of commercial flight recorders exceeded the limitations of GA aircraft. The recent advent of the LDR provides classic and modern GA aircraft with the capability to record audio, video, flight, and GPS data (L-3 Communications, 2010). Air safety investigators face the challenge of persuading and encouraging the general aviation community to adopt LDR technology to enhance safety. Perhaps the most beneficial aspect of LDR is that the information captured provides the foundation to identify the important or missing pieces of the accident investigation puzzle (Hersman, 2012).

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CAMILLE BURBAN, 23, a native of Nantes, Bretagne, France, is currently a Ph.D. candidate at Cranfield University, Cranfield, Bedfordshire, UK, and is enrolled in human factors training for accident investigators. About her career path she says, "Aviation has always been a big interest in my life. I did a small internship in the French navy with Lynx pilots. This spurred a desire to work on onboard electronics. Whilst completing my mechatronics engineering degree in France, I got the opportunity to spend my last year at Cranfield University in order to complete my MSc in human factors and safety assessment in aeronautics. This was a double-degree program. I graduated from both schools this year. I found human factors extremely interesting and got fascinated…and decided to start a Ph.D. this year on human factors training for accident investigation. I hope to become an accident investigator one day and be able to apply my mechatronics and human factors knowledge to improve safety."

Her winning essay follows:

THE CHALLENGES FOR AIR SAFETY INVESTIGATORS: AIRCRAFT ACCIDENT INVESTIGATOR, A VERY INFLUENTIAL ROLE

By Camille Burban

Accident investigations are conducted for several reasons: to meet legal, regulatory, and moral obligations, but also to allocate responsibility, financial, and legal liability. However, the main objective of an air safety investigation is to improve safety. This is done by investigators who try to understand what happened during an incident or accident, why it happened, and how to avoid its reoccurrence by making safety recommendations. This is accomplished through a final report, which details the evidence found, the analysis of that evidence, the conclusions drawn out of the findings, and the safety recommendations. Those are addressed to airlines, companies, manufacturers, regulators, etc. It is the investigator's duty to consider all of the interested parties in this report and yet remain independent from them. Many diverse parties will be affected by, or have an interest in, the report and recommendations. This is where we can see that accident investigators are very influential and therefore have a lot of responsibilities. Indeed, if their recommendations are accepted, procedures, designs, and so on will change in order to improve safety and avoid the same event from reoccurring.

Positively influencing safety can be very challenging in today's aviation where accidents are usually multi-causal. Investigators need to work very closely with industry. They will need to establish if errors or violations have been committed, and yet they will also need advice from industry such as using their experts to identify failures or to assess the feasibility of recommendations. Some state accident investigators such as those within the UK AAIB also fly for an airline in order to stay current.

In order to make the most of their contact with those people, investigators need to maintain credibility. In other words, they need to know what they are talking about, and this is where continuing training is necessary. They have to stay up-to-date with new technology, regulations, procedures, and human factors (it is not a secret that human error is involved in a lot of incidents or accidents, and it is essential to consider it from the start of the investigation to get the most out of the interviews and so on).

The safety investigator also influences the general public and

(continued on page 30)

The Evolution of Accident Investigation Tools And Techniques

From Daedalus to smartphones the history of aviation accident investigation tools and techniques is intertwined with multiple aspects of human existence. Tools and techniques that may have been considered heresy or witchcraft centuries ago are now considered reputable science. Certainly as man's understanding of the world around him has evolved, so have the tools available to analyze flight and its inherent dangers.

By Jay F. Graser (AO6169), Vice President, Gemini Technologies, Gainesville, Va.

(Adapted with permission from the author's paper entitled From Daedalus to Smartphones and NextGen: The Evolution of Accident Investigation Tools and Techniques *presented at the ISASI 2012 seminar held in Baltimore, Maryland, USA, on Aug. 28, 2012, that carried the theme "Evolution of Aviation Safety, From Reactive to Predictive." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org under the tag "ISASI 2012 Technical Papers."—Editor)*

In an accident investigation, how we collect and analyze data drives timely and accurate safety-related changes in the aviation industry. While we are continually bombarded by more technology, we cannot lose sight of the fact that we are still dealing with the positive and negative aspects of having humans in the process. Tools and techniques have evolved around the available technology throughout history; but in the end, the human in the equation becomes the critical factor. Our benefiting from those tools and techniques is dependent on our willingness to adopt and apply them, as well as act on what they are telling us. This is further complicated by the complexity and ambiguity of measuring human factors and behavior.

We can only suppose what prehistoric man must have thought with regard to flight. As I first considered this idea from his perspective, it seemed trivial compared to the daily rigor of survival. Did early man even have the time to contemplate what birds were doing? Maybe he envied their ability to fly to safety or cursed them for flying away when he tried to catch them for food.

However, we can learn from early man. In order to survive, he had to remain aware of his situation and be constantly vigilant. Any complacency on his part would mean giving up his life to the elements, predators, or any number of hazards. While the hazards of flight were probably not first on his mind, we can apply his survival skills and instincts to the analysis of flight. To some degree, our dependence on the very tools we have learned to trust, such as checklists, autopilots, and process automation, may have dulled the situational awareness needed to survive.

Ancient inventors

Some of what we consider modern tools and techniques can be traced back to ancient inventors. For example, the Roman poet Ovid wrote of the inventor Daedalus in 8 A.D. While Daedalus was a mythical character, he gives us an idea regarding the thinking of the time. As the legend goes, Daedalus and his son Icarus were imprisoned in a tower in order to keep Daedalus from giving away the secret of the labyrinth. Daedalus had built the labyrinth for king Minos to hold the Minotaur, a mythical half man, half bull. In order for Daedalus and Icarus to escape from the tower, Daedalus fashioned wings from feathers that were secured with string at the mid-point and wax at the base. He warned Icarus not to fly too close to the sun in order to avoid melting the wax holding the feathers in place. He also cautioned his son not to fly too close to the sea so as to avoid getting the feathers wet. Unfortunately, Icarus became too exuberant and flew close enough to the sun to melt the wax, resulting in the wings failing and Icarus plummeting into the sea and drowning.

In a surface analysis of what we know, was this pilot error or a material failure? Icarus, as the pilot, was trained not to fly too close to the sun; but it appears he became complacent, lost situational awareness, and flew his aircraft beyond the limits of its construction. What was the root cause of the pilot error? Did he not understand the training? Was he fatigued

First fatal accident: On the late afternoon of Sept. 17, 1908, the Wright Flyer, with Orville Wright and First Lieutenant Thomas E. Selfridge, U.S. Army Signal Corps, crashed from an altitude of 75 feet. Selfridge suffered a severe head injury and died three hours later, becoming the first official aircraft accident fatality. Wright survived with serious injury.

and therefore flying with impaired judgment? Only Ovid knew the answers to these questions, but it becomes a good, early example to examine.

5M model

Daedalus' warning to Icarus and the subsequent results can fit well in to the 5M approach to accident investigation. The 5M model illustrates five integrated elements in any system:

Mission: Functions that the system needs to perform.

Man: Human operators and maintainers.

Machine: Equipment used in the system, including hardware, firmware, software, human-to-system interface, and avionics.

Management: Procedures and policies that govern the system's behavior.

Media: Environment in which the system is operated and maintained.

The scenario of Icarus' fate fits into at least three aspects of the 5M model. The man erred in that he did not apply the training he was originally given. The machine failed due to the material's sensitivity to heat, and the media (or environment) played into this in the heat of the sun or the feathers' potential exposure to seawater.

Centuries later, another inventor provides more potential examples of accident investigation tools and techniques. Da Vinci's experimentation with flight certainly showed an observation of the same laws of physics and the properties of aerodynamics that we use in accident investigations today. He wrote in the 1500s that "a bird is an instrument working according to a mathematical law." His experiments applied mathematics to help explain how birds fly. Today, we use that same mathematics to explain why an aircraft might have stopped flying. From a practical perspective, Da Vinci took us from simply observing flight characteristics to capturing them in an objective mathematical expression. Consider that this concept of a mathematical law is the basis for the modeling and simulation that we use to routinely recreate accident scenarios.

Today's basic tools

Typically investigators carry wrenches, screwdrivers, and devices peculiar to their specialty. All carry flashlights, tape recorders, cameras, and lots of extra tape and film. The NTSB Major Investigations Division (AS-10) has two "flyaway" suitcases available for use during the investigation. The two kits contain such things as a video camera and tape, laptop computer, printer, various charging devices, film, administrative supplies, and copies of the investigator's manual. The tools themselves are rather straightforward; the key is in the evidence these tools allow investigators to collect and how we make sense of that evidence.

Recorders

Instrumentation available to support accident investigations includes cockpit voice recorders, flight data recorders, and quick access recorders. Flight data recorders were suggested as far back as 1941 but were put on hold until 1947 due to a lack of parts during the war. Even as late as the 1960s, flight recorders may have been installed but not necessarily turned on, especially for training flights. Newly manufactured aircraft are required to be equipped with a flight data recorder that collects a minimum of 88 parameters. As aircraft systems become more complex, we can expect the number of available parameters to grow.

In 1998, Barry Sweedler, NTSB Office of Safety Recommendations and Accomplishments director, presented to the 4th World Conference on Injury Prevention and Control the case for having more parameters available. For example, in the ATR 72 accident in Roselawn, Indiana, in October 1994, the flight data recorder captured information on 115 parameters, as opposed to the currently required minimum of 88. Reading out the recorder in the NTSB laboratories, they were able to spot the telltale, rapid movement of an aileron control and issue safety recommendations within a week. Conversely, B-737 incidents where as few as five parameters were being recorded took several years before the NTSB could make recommendations regarding the B-737 rudder system. Sweedler also pointed out the value of using quick access recorders for their ability to be easily downloaded after each flight in order to identify deviations from procedures and drive improvements.

Aviation Safety Information Analysis and Sharing system

In order for data to be of any use, it needs to drive the appropriate action. Data collection and analysis challenges include consistent and objective collection at the point of occurrence, data standardization such as using common descriptions and units of measures, filtering out bias of the person doing the collection, data normalization, equal access to data, statistically valid interpretations of the data, and recognizing the significance of the data in order to drive action.

Aviation Safety Information Analysis and Sharing (ASIAS) is one solution to providing equal access to data. The ASIAS system connects 131 data and information sources across the aviation industry and is integrated into the Commercial Aviation Safety Team (CAST) process. Of those sources, 46 are safety databases, 78 are hybrid databases, and 7 are standards datasets. There are currently 42 member airlines participating in ASIAS. Since it began in October 2007, the program has evolved to the point that ASIAS now has access to Flight Operations Quality Assurance (FOQA) programs from 24 operators and Aviation Safety Action Partnership (ASAP) data from flight crews, maintenance, and other employees from 40 operators.

ASIAS is also accessing reports in the Air Traffic Safety Action Program (ATSAP), which provides air traffic controllers with a way to report potential safety hazards. Other Air Traffic Organization (ATO) employees will be added to the program in the future. One major accomplishment is that seven of CAST's

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76 safety enhancements have been derived from forward-looking data analysis in ASIAS. Additionally, ASIAS stays connected to CAST's safety enhancements to track the effectiveness of those safety interventions. ASIAS presently has four CAST metric categories in active monitoring comprising 51 distinct metrics. Infoshare, a semiannual closed-door meeting of more than 500 airline safety professionals, facilitates sharing of safety event identification and mitigation. It's linked to ASIAS for early detection and analysis of safety issues.

The FAA plans to eventually expand ASIAS to 64 databases. Current examples include

- ACAS (Aircraft Analytical System)
- ASAP (Aviation Safety Action Program)
- ASDE-X (Airport Surface Detection Equipment, Model X)
- ASPM (Airspace Performance Metrics)
- ASRS (Aviation Safety Reporting System)
- ATSAP (Air Traffic Safety Action Program)
- FOQA (Flight Operations Quality Assurance)
- METAR (Meteorological Aviation Report)
- NFDC (National Flight Data Center)
- NOP (National Offload Program Office Track Data)
- SDR (Service Difficulty Reports)
- TFMS (Traffic Flow Management System)
- TOPA (TCAS Operational Performance Assessment)

ASIAS uses FOQA and ASAP data from 40 air carriers that represent 95 percent of commercial operations in the national airspace system (NAS). Available data include

- current number of ASAP reports: 110,000.
- current number of FOQA reports: 8.1 million.
- current number of ATSAP reports: 50,000.

The FAA plans to increase the numbers and types of participants following a phased expansion plan to include other parts of the aviation community. ASIAS will include domestic corporate general aviation, military, helicopter, manufacturers, and other government agencies.

Info glut

The amount of data available from ASIAS and other sources is staggering. While it would seem like a good thing to have as much data as possible, when is it too much and therefore a glut of information?

Data are not much good to the aviation community unless they can be analyzed in a timely manner. For the answer to dealing with what appears to be a glut of data, we can turn to the companies that derive their living making sense of large volumes of information, such as Google, Facebook and Amazon.

For example, Google processes more than 20 petabytes (one million gigabytes) of data per day, and this is only expected to increase as more processing and data storage are done away from the end-users' hard drives using cloud computing. Also, Amazon is growing at such a rate that it adds as much capacity to its data centers each day as the whole company ran on in 2001. Despite this daily torrent of data, these companies have been able to develop algorithms that drive daily business decisions. This puts the contents of ASIAS into perspective. Rather than potentially limiting the flow of data in order to make it more tolerable, we should be leveraging existing expertise in data analysis to take advantage of new sources of data, such as smartphones and the flow of data that will become available through NextGen.

Reactive to predictive

The transition from reactive to predictive can be considered along a continuum. While it would be nice to think that we always progress along the continuum toward predictive, human nature has shown that while we have the tools available to predict and possibly prevent some accidents, our emphasis swings back and forth from reaction to prediction and back again. Unfortunately, sometimes it takes the reaction to a fatal accident to galvanize people into action. It is our responsibility as aviation safety professionals to continually put the emphasis on the tools and techniques that support prediction and accident prevention rather than reaction.

When a balloon crashed in Tullamore, Ireland, in May of 1785 and destroyed more than 100 homes, the reaction was not quite what we might have expected today. If this were to happen in modern times, there would have been a cry for limiting balloon operations over populated areas and an increase of available fire protection. Instead, despite the event's coverage in the newspapers of the region, they took virtually no action at all. In fact, a fire brigade wasn't even commissioned until 1886 when the tobacco factory burned down.

When Army Signal Corps Lieutenant Thomas E. Selfridge was killed in 1908, he was considered the first casualty of powered flight. The Wright brothers' reaction to the event was swift. Immediately after the crash, Lorin Wright told reporters, 'My brothers will pursue these tests until the machines are as near perfect as it is possible to make them—if they are not killed in the meantime." In this case, testing was driven by a reaction, rather than initiated as an effort to predict an accident.

Prediction

Evolving from reaction to prediction has been facilitated by changes in policies and directives over the years. Early in the history of aviation, the objective of an accident investigation was to apportion blame. The guidance first established in 1928 by the U.S. National Advisory Committee for Aeronautics applied a credit system of factors. For example, an accident could be determined to be 70% pilot error (Man) and 20% mechanical failure (Machine) and 10% weather (Media). However, the International Civil Aviation Organization's (ICAO) Convention on Civil Aviation ("Chicago Convention") of 1944 and further refinements in 1946 and 1947 began a shift from identifying blame to sharing lessons learned. This later became Annex 13 of the Convention (12). Annex 13 paved the way for information sharing, such as ASIAS, that would emphasize lessons learned to the benefit of all stakeholders in the prediction and prevention of accidents, rather than laying blame as a reaction to the accident.

To predict potential accidents, we need to be able to take the data we have and extrapolate that data into the future. Representing aviation systems as a mathematical or physical model gives us a way to do this. Da Vinci was well known for his scale drawings and models of aircraft. Today, we have evolved to high-fidelity Level D simulators that allow us to train pilots with such accuracy that they are fully qualified by the time they reach the actual aircraft. These same simulators are used to run through a multitude of emergency scenarios in order to help develop procedures to deal with almost any failure.

In addition to modeling the performance of the aircraft, we can process large volumes of data to identify potential accident risks. Along these lines, the Indian Air Force (IAF) has developed the Accident Probability Factor (APF) calculator. APF uses actuarial science and mathematical algorithms to analyze archived data of the last 30 years to predict accident probabilities of flying.

Additionally, equipment manufacturers collect data during component testing. These data are used to create mathematical models of aircraft components and systems that predict when they will fail. For example, Mean Time Between Failure (MTBF) is a common metric used to predict when parts will fail. Airlines spend millions of dollars a year in preventative maintenance to replace parts based on these component failure predictions.

Also, mathematical models and simulations of ever-increasing air traffic and how best to route aircraft have helped to address the Management aspect of 5M and driven efforts such as NextGen. Weather models tell us where and when to fly. This combined with the flexibility of route planning offered by NextGen will simplify routing flights around weather hazards. These factors combined cover at least the Machine and Media, and to some degree the Management, aspects of the 5Ms.

However, if 50% of aircraft accidents can be attributed to pilot error (see Table 1), it seems important to emphasize tools and techniques that allow us to model the Man aspect of 5M. Dr. Steven Hursh of Johns Hopkins states that current models of fatigue, in combination with models of how work/rest schedules limit expected levels of sleep, can provide surprisingly accurate predictions of the fatigue tendencies of the average person and the risk of performance failure. Properly conceived, models of the average person can predict increases in accident risk and severity. Modeling of the effects of fatigue has been ongoing with agencies such as the Department of Defense, Department of Transportation, NASA, and the FAA resulting in various fatigue risk management tools.

Table 1: Causes of Fatal Accidents by Decade (percentage)

CAUSE	1950s	1960s	1970s	1980s	1990s	2000s	All
Pilot Error	41	34	24	26	27	30	29
Pilot Error (weather related)	10	17	14	18	19	19	16
Pilot Error (mechanical related)	6	5	5	2	5	5	5
Total Pilot Error	**57**	**56**	**43**	**46**	**51**	**54**	**50**
Other Human Error	2	9	9	6	9	5	7
Weather	16	9	14	14	10	8	12
Mechanical Failure	21	19	20	20	18	24	22
Sabotage	5	5	13	13	11	9	9
Other Cause	0	2	1	1	1	0	1

Future tools

The discovery of future tools may be dependent mostly on our willingness to apply them. A 1966 report regarding flight recorders stated: "Because of the flight recorder's ever-increasing importance in aviation, it is imperative that everyone associated with accident investigation and prevention should become familiar with this instrument—not necessarily with its mechanical and electronic features, but with its role in the investigative process, what it can and cannot do, and, above all, its potential." Consider that at the time the report was written, flight recorders had been in use to some degree as early as 1941. Yet 25 years later, we see the above plea to include them in the investigative process.

What is the next future tool or technique, like the flight recorder, and are we prepared to integrate it into the investigative process? Will it take us 25 years to begin applying it in the investigative process? Along these same lines, the following are tools that may have potential, but we cannot take another 25 years to integrate them into our processes.

Smartphones—There are several aspects of smartphones and similar devices that could be helpful, including additional data points for an investigation, prediction of accident risks, and ongoing training and performance support. For example, leading up to an accident, passengers may be talking on their cell phones. While current U.S. regulations prohibit this, during a dire emergency passengers and crew may disregard the regulation. In the case of the 9/11 hijackings, we were able to learn a great deal by analyzing the conversations between the passengers and the ground.

Also, some airlines are beginning to allow talking on cell phones at altitude. Virgin Atlantic announced in May of 2012 that its newest Airbus widebody will be equipped to allow talking while over the ocean, far away from land. Other planes so equipped are sure to follow. This is not a new occurrence—some Middle East carriers started allowing cell phone calls in flight a couple of years ago.

While constant talking is probably annoying to those sitting around the phones, it creates another data source for an investigation. Consider the additional voice data that may help investigators if an emergency occurs and a cell phone is able to pick up audio of the event that can provide additional clues. In the case of the 1996 ValuJet crash in the Everglades, the first indication that there was a fire aboard was when shouts of "fire" were picked up by the cockpit voice recorder from the passenger cabin.

While the inadvertent audio picked up by a cell phone in operation during an emergency may seem to be of limited value, consider that smartphones also measure parameters such as acceleration, attitude, and GPS location, depending on what functions may be turned on at the time. Many smartphones track and store these data, which in the future could become helpful in an investigation. In one possible application, if smartphones survive the impact, their GPS function could be used to more readily locate scattered wreckage comingled with the phones.

As a performance support tool, a smartphone could fulfill many roles. In order to predict risk from fatigue, exercises could be programmed into the phone that allow the pilot to periodically test his fatigue level, including before, during cruise, and after a flight. This would serve two purposes. It would give the crew a better and more objective awareness of their fatigue level, and the data collected could be transmitted to a central database and be analyzed for trends related to fatigue and other critical performance factors.

The smartphone could also be used for problem solving exercises to ensure pilots are not simply following routine checklists but remain situationally aware and able to prioritize and solve problems. How many aircraft have crashed because the crew was involved in troubleshooting something as simple as a blown indicator light and lost situational awareness and the priority to "aviate" first.

Current prediction tools are still very general about the factors that increase accident risk. It is virtually impossible to apply them to a specific flight that is about to occur and change a potentially disastrous outcome. However, consider the ability to analyze

thousands of factors in real time to predict the risks of a particular upcoming flight. Using a smartphone as a terminal to cloud applications, we could place the power to change the outcome in the hands of the schedulers and the pilots preparing to fly, rather than just long-range planners and managers. Factors such as current weather, crew dynamics, fatigue, and the particular aircraft's vulnerabilities could all be summarized into a hand-held interface that facilitates decisions in real time.

Smartphones can also be applied as a performance support tool during an investigation. Rather than rely on paper-based collection tools or carrying around a tablet computer, a smartphone can be used during the collection of data, such as documenting the location of crash debris.

For example, the GPS in the smartphone allows the investigator to take a picture that is synchronized to the location where the picture was taken, and the voice-to-text function allows the investigator to document comments at the time and place the evidence or debris is located. This reduces the possibility that the data could get lost or distorted by waiting until the investigators are back at the command post to enter their observations into their laptops.

Additionally, current off-the-shelf smartphone apps enable the device to read barcodes that might be on aircraft parts. With the addition of a small, Bluetooth-enabled reader, the phone can also read RFID tags. Since many components have barcodes on them and some suppliers have started using RFID tags, this would make identifying and cataloging parts found at the scene much easier and reduce the risk of entry errors.

Human Behavior Measures—In a June 2012 CBS interview, David Soucie, author of *Why Planes Crash: An Accident Investigator's Fight for Safer Skies*, discusses an "atrophy of vigilance." He notes that while tools such as checklists ensure every item during a flight is considered, they tend to automate the decision process. Repeatedly following checklists by rote, we can lose situational awareness and miss the obvious. The checklists tend to dull our ability to apply basic problem solving.

Here is an anecdotal example of this phenomenon: During my career in aviation training, I have noticed a cycle from training only procedural knowledge with no theory to teaching aviators deeper theory and systems knowledge and encouraging them to apply basic problem solving in addition to the procedures. While it can be more expensive to take the time to train the foundational theories and systems knowledge, the result is the ability to solve problems—which may not have been considered when the checklist was written.

As a case in point, in the early 1980s the USAF trained foundational knowledge of theory and systems knowledge to their C-5 Galaxy crewmembers. However, in the mid to late 1980s, the C-5 aircrew training focused less on foundational knowledge and more on simply following procedures. In short, the latter approach was analogous to "flip the switch per the checklist, but don't be concerned with why you flip the switch." As the procedurally trained crewmembers were deployed to make up crews and integrated with those crewmembers having more foundational understanding, there were complaints from the field.

While the C-5s are not the oldest airplanes in the USAF fleet, their complexity, combined with their age, makes them somewhat temperamental to operate and maintain. The substance of the complaints from the field was that the procedurally trained crewmembers were not given the skills and understanding needed to apply basic problem solving to the myriad of possible failures and potential workarounds. This meant that either sorties would be delayed or missions aborted in flight due to an inability to resolve the problem. Yet, the foundationally trained crews were more readily able to go beyond the constraints of the procedures and checklists in order to solve problems. Their solutions were often creative, yet technically legal, and kept the aircraft flying and able to complete the mission.

What tools are in the future that could be used to measure and trend behaviors that indicate complacency? Once those behaviors are identified, can we predict the potential for an accident and put exercises in place to reduce complacency and increase situational awareness and problem solving? Our most valuable tools may be those that measure these behaviors and allow us to put in place tools to change the behaviors. Aircrew members are pressed for time to begin with, so the answer is not necessarily spending time in more traditional training. The answer may be designing into the aircraft events that prompt the aircrew to respond in ways that show they are situationally aware. One potential approach may be creating mobile applications that allow aircrew to practice problem solving on their smartphone while deadheading to their next location or during other down time.

NextGen

NextGen's satellite-based routing will provide precise data regarding the aircraft's position to both air traffic controllers and other aircraft. Automatic Dependent Surveillance–Broadcast (ADS-B) enablers broadcast the aircraft's position and certain other data. Ground receivers and other aircraft within range can receive these broadcasts and use them for their own applications. Using ground receivers across the country, controllers will receive and process precise ADS-B broadcasts to provide air traffic separation and advisory services. This data precision will be invaluable to accident investigators in reaction to an accident.

NextGen will also enhance safety management via the Safety Analysis System (SAS), which will provide an automated environment for analyzing, predicting, and addressing NAS-wide safety risks and enable users to extract information from multiple databases and systems. With a functioning SAS, ATO will be able to collect, assimilate, share, analyze, and view information to ensure that all NAS users have a consistent view of system safety. SAS will facilitate risk-based decisions and enhance the agency's predictive capabilities. SAS, an internal ATO system, will complement ASIAS by drawing data directly from some NAS sources not tied to ASIAS. SAS will also be capable of sharing safety data with the ASIAS platform.

The evolution of tools and techniques used in the investigation, prediction, and prevention of aircraft accidents has only been limited by the available technology and our willingness to apply it. We can see that even in the time of Daedalus they considered factors such as weather and aircraft design limitations, yet in the end the failure was the human in the process. Hopefully, future tools and techniques will focus on harnessing the human aspects of the process, such as situational awareness, problem solving, and survival. ◆

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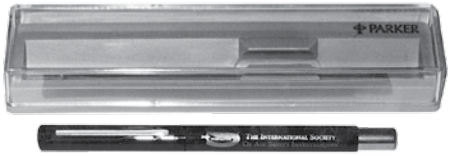

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(continued from page 23)

the families of those involved in an accident. Accident investigation gives answers to those people. Some will expect "a name"; they want to know who to blame. But it is not the role of a safety accident investigation. It should be blame free in accordance with ICAO Annex 13. What the investigators are going to tell those people can have a very strong effect on them—for example, following the Uberlingen mid-air collision. This is why regular meetings and reports are extremely important to keep them informed. The UK AAIB, for example, does a very good job with its special bulletin, interim reports, and family briefings to ensure that the families understand the truth rather than a journalist's interpretation. Dealing with the news media is actually a major challenge in itself. It is about giving information so reporters respect the investigation, but giving correct information and protecting the people involved, which is not always easy as during the first days of an investigation many answers are not known.

In addition to being not-for-blame or just, safety investigations have to be independent. This means independent from the industry as well as the regulator as their recommendations will influence their decisions. This is also to avoid any corruption. The Nigerian example has been used to illustrate the importance of having an autonomous investigation branch. It improved the overall safety in the aviation industry of this country. Other African countries have even been encouraged to follow this example.

Last but not least, the investigators' role is important during inquests. Indeed, after the blame-free, independent safety investigation, a judicial investigation may be conducted in order to identify who has a responsibility in the event. This will be done by the judicial system of the countries involved, and the safety investigators may be called in court in order to justify their statement. What they will say or write is key evidence in this kind of investigation. Their credibility is also essential so their statement is taken seriously. This is where sometimes the use of an expert for a very specific field of investigation (human factors, coroner, etc.) is useful.

In conclusion, during a safety investigation, accident investigators will have to deal with different stakeholders. Some take part in the investigation or at least work with it, such as technical experts or interviewees such as regulator, manufacturer, airline, training provider, maintainers, and other accident investigation agencies. Some just want answers, such as insurers, families, news media, etc. The main challenge for accident investigators is to deal with all those people at the same time, as well as running the investigation, blame-free and independent. While news media and families will want somebody to blame, airlines and manufacturers might protect their interest. The investigators' decisions, statements, and recommendations will influence all those stakeholders. The challenge is also in the fact that investigators will need those people to run the investigations and obtain answers. Dealing with, working with, judging, giving answers are all the roles that an investigation has to play, sometimes with a single entity. ◆

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WHO'S WHO

Air Group (Airinc) Comprises Two Roles

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

The AIR Group is an international aircraft accident investigation and safety systems software development and services company that comprises two distinct companies, Accident Investigation and Research (AIR) Inc. and Applied Informatics and Research (AI) Inc. Together they comprise the AIR Group with offices based in Ottawa, Canada.

The firm was founded in 1983 by three Transportation Safety Board of Canada Engineering Branch investigators, Terry Heaslip (one of the original ISASI Fellows), Robin McLeod, and Max Vermij. In 1998 Steve Roberts joined the firm as a full partner, followed by Larry Vance in 2008 after Vance helped lead the technical investigation into the Swissair 111 loss in Peggy's Cove, Nova Scotia.

Today the company is a well-established aircraft accident investigation consultancy firm that has served hundreds of clients on many hundreds of investigations worldwide, including those that involved the largest losses in the world. The company specializes in the human-machine-environment investigation process, linking these areas together in a coherent investigation methodology. AIR is able to provide expertise in areas such as human factors, metallurgical and materials analysis, system analysis, fire and explosives investigation, performance and flight data, cockpit voice recorder and radar data analysis, computer engineering analysis, and animation and still graphics demonstrative presentations. The company also teaches aircraft accident investigation internationally.

Applied Informatics and Research (AI) Inc. was founded in 2007 and specializes in flight data and cockpit voice recorder and radar data computer analysis and presentation. The company produces its own Flight Analysis System (FAS) software suite for commercial distribution to civil and military accident investigation authorities, commercial air operators and maintenance organizations, and organizations that are involved in the readout, analysis, and interpretation of flight data and cockpit voice recorders information.

AI also produces a highly sophisticated computer animation software tool that allows for the three-dimensional presentation of flight data through multiple visual viewing environments (this program is known commercially as FASET). AI also offers managed services primarily in the area of hosted Flight Operation Quality Assurance (FOQA), Flight Data Monitoring (FDM), and Flight Data Analysis (FDA). As part of the service, AI offers complete hosting of the operator's data and analysis process, including daily and weekly reporting up to and including monthly safety briefings by its pilot expert staff, always while working in close partnership with the operator.

The company prides itself on its mathematical and statistical approach to flight data analysis, which it has developed in partnership with major clients, producing some of the most comprehensive safety and economic analysis reporting modules in the industry. In order to round out these comprehensive solution offerings, AI has also formed and is actively seeking strategic partnerships with industry-leading software and hardware manufacturers.

The AIR Group is a world leader in its comprehensive knowledge of the aviation industry, encompassing aircraft accident investigation, Flight Operational Quality Assurance (FOQA/FDM/FDA), economic and safety performance Analysis, and specialized software development products and services. Clients are able to derive benefit from this multidisciplinary knowledge-based approach, all housed within one common facility. ◆