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ABOUT THE COVER
Airbus participated as part of a team (see page 12) to investigate the 2015 crash of an A321. The investigation included assembling a layout of recovered wreckage on a grid that was completed in only a few days. This process allowed the investigation team to concentrate on particular areas of interest.
Aircraft accidents create a great deal of trauma and misery for surviving passengers and flightcrew members, families, and people present at the impact site. Air accidents and incidents can also be difficult for other people in the world who are not directly affected, but who feel empathy and compassion for those directly involved even though they are strangers.

ISASI members realize that every accident and incident is an opportunity to improve aviation safety and survivability. Safety is enhanced if we, as investigators, do a thorough job and make meaningful safety recommendations that get acted upon. Last year’s annual ISASI seminar theme was “Do Air Safety Investigations Really Matter?” The consensus of technical papers presented was clearly, yes, they do.

That knowledge helps us deal with trauma-induced stress that we face in our profession. But sometimes more human interaction is needed. Airlines, aircraft manufacturers, and employee organizations recognize the adverse consequences of facing such trauma and have developed very successful crisis stress intervention programs to help responders cope. In addition to improving air travel safety, investigations bring together a wide range of people who sometimes develop life-long professional relationships and personal friendships. This includes governments, industries, unions, first responders, operators, and anyone involved in the investigation.

Another aspect that sometimes occurs as a result of human interaction on investigations—it is extremely rare, but it does happen—investigators fall in love and get married.

On April 4, 1977, Southern Airways Flight 242, a DC-9-31, crashed in New Hope, Georgia, USA, following an encounter with hail that caused a loss of thrust in both engines. Seventy-two people were fatally injured, including nine on the ground. There were 27 survivors.

The U.S. National Transportation Safety Board (NTSB) investigated the accident, and Matt McCormick was the chair of the Survival Factors Group. Patricia Hopkins, a flight attendant with Southern Airlines, was on the team representing the Transport Workers Union. About two years later, Matt and Patricia came together while testifying at a U.S. congressional hearing on airline deregulation. They married in 1980 and now reside in Surf Side Beach, South Carolina, USA.

There was a second marriage—one that followed the American Airlines Flight 191 accident in May 1979, in Chicago, Illinois, USA. The accident fatally injured 273 people, including two people on the ground. Dr. Andy Horn, representing the U.S. Federal Aviation Administration (FAA), was on the Survival Factors Group. Kathy Russo was on the team representing the Association of Professional Flight Attendants. They were married shortly after the accident. Horn passed away about 10 years ago, and we were unable to locate or obtain information on Russo.

On June 8, 2018, Michiel and Julia Schuurman were married at the Delft City Hall, in Delft, the Netherlands. They first met in Kiev, Ukraine, following the Malaysia Airlines Flight 17 shootdown that occurred on July 17, 2014. At the time, Michiel’s employer was the Dutch Safety Board, and he was a member of the accident investigation team. Subsequently, he accepted employment with Delft University of Technology as an associate professor teaching aviation-related subjects. Michiel had originally graduated from Delft University.

Julia studied in Kiev at the National Aviation University. After graduation, she worked at the National Bureau of Air Accidents Investigation of Ukraine and was part of the Ukraine investigating team. She subsequently enrolled as a Ph.D. student at Delft University in aerospace engineering. Both Julia and Michiel were on break and met in the hall. Sparks flew, and the rest is history.

Michiel was the first recipient of ISASI’s Kapustin scholarship in 2003, which led to his employment with the Dutch Safety Board. In addition, at the Adelaide, Australia, seminar in 2014, Michiel shared the Award of Excellence for best seminar paper with Kas Beunkes, a fellow employee at the Dutch Safety Board. ISASI extends congratulations to Michiel and Julia on their recent wedding. ✩
ANALYSIS TECHNIQUES FOR INVESTIGATING HUMAN PERFORMANCE

By Randy Mumaw, Researcher, NASA Ames Research Center; William Bramble, Senior Human Performance Investigator, NTSB; Joel Morley, Former Senior Human Factors Investigator, Transportation Safety Board of Canada; and Fanny Rome, Human Factors Safety Investigator, BEA.

A casual reading of popular print and online communications can lead one to believe that human error is the leading cause of airplane accidents. Consider the following claims:

- A 2007 article in Boeing’s trade magazine, Aero, stated that “humans are the largest cause of all airplane accidents” and “approximately 80% of airplane accidents are due to human error.”
- From the BBC: “How human error can cause a plane crash.”
- In the Independent in 2015: “Human error has been revealed as the biggest cause of air disasters around the world.”
- In a report by the UK civil aviation authority: “Two-thirds of all fatal accidents involved a flight crew–related primary causal factor.”
- There is the Wikipedia page titled “Airliner accidents and incidents caused by pilot error” that lists several hundred accidents and incidents.

Human error and accidents

These types of pronouncements lead the public to the unambiguous conclusion that “human error causes accidents”—a strongly misleading claim. Certainly, these communications sources are less concerned about trying to explain the complex nature of causation, but a few of these strong statements regarding causation are coming from the aviation industry.

For aviation safety professionals, it should no longer be acceptable to make the claim that there is a single “cause” behind any accident or incident. As we now know, accidents are the result of some combination of latent failures, unexpected situations or failures, underlying organizational policies and practices, degraded environmental conditions, and the actions of pilots, maintenance technicians, and controllers. Previous studies offered useful insights into how these various influences can come together. We—the members of this panel (the authors who presented this material during ISASI 2017)—seek to promote a similarly nuanced understanding of how human performance contributes to accidents (and to safety).

It is true that human performance contributes to a majority of aviation accidents and incidents, but it is important to recognize that human performance is one of many contributors to an accident and is shaped by contextual or system factors. Unless we clearly understand the factors contributing to human performance in an occurrence, resulting safety action will be poorly targeted or superficial. For this reason, we would prefer to see the identification of human error as a starting point for analysis, not an end point. With that goal in mind, we strive to offer analysis techniques that can reveal important influences on human performance.

Those who came before us

Not surprisingly, others have examined this topic. Notably, the theme of the Society of Air Safety Investigators second annual meeting in 1971 identified a need for a more complete analysis of human performance. At this meeting, U.S. National Transportation Safety Board (NTSB) manager Chuck Miller declared human factors (HF) the “greatest single technological challenge” facing society. At the time, interest in HF was prompted by unsatisfying conclusions in some accident reports. For example, an accident involving a Convair 340 that crashed in New Haven, Connecticut, USA, was explained in terms of the captain’s intentional descent below minimums. The report concluded that the board was “unable to determine what motivated the captain to disregard prescribed operating procedures...and finds it difficult to reconcile the actions he exhibited during the conduct of this flight.” Aviation industry representatives expressed dissatisfaction with such findings, saying they left the industry with the unhappy choice of explaining accidents in terms of suicidal flight crews or complete incompetence.

To better address the concerns, the NTSB began to hire human performance investigators to dig into underlying HF and organizational causes. The NTSB hired its first human performance investigator in 1977 and established a stand-alone group by 1983. This group began probing more deeply into systemic issues, which was reflected in more expansive causal statements, like one from the investigation of a crash in Rockland, Maine, USA, that cited management pressure, supervision, training, procedures, and fatigue. Other national transportation accident investigation agencies followed suit.

The French Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile (BEA) more thoroughly investigated HF issues during the investigation of an A320 accident in Mont Saint-Odile, France, in 1992. Afterward, the BEA worked with HF institutes and gradually introduced HF academic courses into the training curriculum for all BEA investigators. The Transportation Safety Board of Canada (TSB) has employed dedicated HF investigators since the late 1990s and provides all of its investigators with training in investigating for human and organizational factors.

In the recently published Human Factors in Air Transportation Systems, the chapter “Accident Investigation,” which William Bramble authored, offers a history of advancements in investigating human performance. This chapter provides a detailed tour of the major shifts and mileposts, including the establishment by NASA of the CRM (crew resource...
useful methods and tools have been developed more recently, it has been these influences actually were present and influenced performance. While provided only lists of potential influences on human performance. Inves of standard analysis methods and tools. Early ICAO documents on HF substantial cadre of HF investigators has also limited the establishment cy areas to create an effective HF investigative capability. The lack of a documenting evidence. necessary background in investigative skills, such as interviewing and standing of HF theories and paradigms. Neither approach provides the background in aviation is unlikely to promote a sufficiently deep under HF expertise needs to be integrated with knowledge of airline operations and an understanding of the investigation process. A formal education in HF is unlikely to produce the full range of skills required, and a technical background in aviation is unlikely to promote a sufficiently deep understanding of HF theories and paradigms. Neither approach provides the necessary background in investigative skills, such as interviewing and documenting evidence.

Investigation agencies must find ways to develop all three competen-
cy areas to create an effective HF investigative capability. The lack of a substantial cadre of HF investigators has also limited the establishment of standard analysis methods and tools. Early ICAO documents on HF provided only lists of potential influences on human performance. Investigators were not given analysis methods or tools to determine whether these influences actually were present and influenced performance. While useful methods and tools have been developed more recently, it has been

Bramble also gives ample space to the Australian Transport Safety Bureau (ATSB) document “Analysis, Causality, and Proof in Safety Inves-
tigations” (2007), which addresses the concept of causation, links from evidence to conclusions, establishment of standards of proof, investigative stop rules, and a refined language for probability that is used in ATSB reports. This ATSB document establishes a standard for rigorous analysis of HF issues in accident investigations. The Bramble chapter provides a sense of the foundations of human performance investigation. Investigations also require practicable investigation techniques.

In the following sections, the individual ISASI 2017 panel members offer specific methods and tools to support understanding the influences underlying human performance.

Two HF issues need addressing (Randy Mumaw)
Thanks largely to the efforts of the members of ISASI, accident investigation has made significant strides in shifting to a more nuanced and complex account of accident causation and to a deeper analysis of “human error.” Indeed, commercial aviation has made such strides in its approach to managing safety that industries such as health care and process control have sought to emulate our approach. Although these important shifts are occurring around the world, there is still a need to address two issues:

1. Inconsistent access to HF expertise and methods
HF expertise, especially as it applies to accident investigation, is well established in a number of the investigation agencies around the world.

We, the authors of this article, are testament to the increasingly important role that HF is given. However, this expertise is still sometimes unavailable to smaller investigations, and there have been cases in which critical system factors that affected human performance were not addressed fully. Part of the explanation for this state is that to develop the right people, HF expertise needs to be integrated with knowledge of airline operations and an understanding of the investigation process. A formal education in HF is unlikely to produce the full range of skills required, and a technical background in aviation is unlikely to promote a sufficiently deep understanding of HF theories and paradigms. Neither approach provides the necessary background in investigative skills, such as interviewing and documenting evidence.

Investigation agencies must find ways to develop all three competen-
cy areas to create an effective HF investigative capability. The lack of a substantial cadre of HF investigators has also limited the establishment of standard analysis methods and tools. Early ICAO documents on HF provided only lists of potential influences on human performance. Investigators were not given analysis methods or tools to determine whether these influences actually were present and influenced performance. While useful methods and tools have been developed more recently, it has been
difficult to establish standards or even best practices.

2. The remaining vestige of the “bad pilot” approach

The “person” view of human error from decades ago focused on the close proximity of the error to a bad outcome and concluded that the human triggered the catastrophe. There was less emphasis on determining the influences on that performance, and it led to the idea that if we remove the pilots who make errors from the system, the system would be safer.

Our evolving view now accepts that pilots—indeed, all humans—make errors, and an effective operational system needs to be resilient when errors occur. We need to understand that there is a range of pilot skill and knowledge within the qualified pilots worldwide; that there are daily influences on performance and proficiency, such as fatigue, operational pressures, crew dynamics, and complacency in a safe system; and that flight crew responses to failures and upsets are trained but not to the point that the appropriate response is highly reliable. Airlines strive to balance training costs and pilot proficiency.

There is more work to do. Some accident reports have noted that the accident pilot’s training record showed less-than-perfect performance, such as a failure to concentrate or a low score for situational awareness. The implication seems to be that this pilot, who failed to perform as expected in the accident flight, had weaknesses that were revealed in training, and therefore that pilot was unable to perform across the full range of operational situations. Stated more strongly, “This pilot was ‘qualified,’ but there were some known weaknesses, and this pilot finally found a situation that he or she was not able to handle. The pilot should not have been flying.”

This is a version of the “bad pilot” approach to safety because it makes the suggestion that the pilot was not truly qualified for the job. However, the system needs to be able to accommodate pilots who, even though they are qualified (by regulation), do not concentrate fully during a five-hour flight or are slow to respond to a stickshaker because they did not expect it. This will always be the state of pilots worldwide.

To be clear, it is appropriate to point out when a pilot lacks the training that ensures he or she is fully qualified or that a training performance standard was not enforced. These are system issues to be addressed. But when a pilot has met the performance standards in the prescribed manner, it does not advance the investigation to point out that he or she had a weak evaluation in the past.

To advance the state of the art of accident investigation, HF professionals need to provide analysis methods and tools that can move us beyond the identification of a human error. The following are two tools that have been effectively applied to human performance.

Spatial disorientation/vestibular illusions

Around 2008, I conducted an analysis that suggested that spatial disorientation (SD) had been a factor in a number of commercial transport accidents and incidents. Indeed, SD may have played a role in about 20 accidents and major incidents since 2000. The concern regards two types of vestibular illusions, a somatogravic illusion and a somatogravic illusion. When the external view of the world is lost or degraded due to weather or darkness, a pilot can be strongly influenced by vestibular illusions and make control inputs that lead to a loss of control or pitching down into the terrain.

These vestibular illusions cannot be observed, but the control actions of the pilot are observed and recorded, and these actions can be cast as pilot error. In order to investigate the potential role of vestibular illusions, Boeing worked with a Dutch company, TNO, to develop an analysis tool that determines the accelerations at the point of the pilot flying and uses those accelerations to determine the likelihood that a vestibular illusion could account for the control inputs. Although this tool cannot definitively determine that the pilot was influenced by SD, it offers a way to test whether inappropriate pilot actions are consistent with misleading vestibular cues.

Interface support for responding to nonnormals

When airplane system failures occur, the flight crew should take the following actions: Detect that an important change occurred (an alert), understand the nature of that change, determine what actions (if any) should be taken in response, determine the priority for the response in the context of everything else going on, and then execute the appropriate actions. Ideally, the flight deck interface and its associated procedures aid the flight crew in completing this sequence accurately and completely. An assessment method, called CREW, allows an analyst to identify both factors that support this performance and factors that make performance more difficult.

The assessment method consists of evaluating the sequence of actions using a set of more than 100 help and hinder prompts, i.e., in the case of detection, what factors help, or aid, detection and what factors hinder detection. An example of what can help detection is a salient alert; an example of a detection hinder is when there is no alert and the pilot must compare current airplane performance to some internally defined standard, such as feel. An example of what can hinder determining actions is when the nonnormal checklist is not associated with an alert (such as unreliable airspeed in many airplanes). In that situation, the flightcrew members are required to recall that there is a relevant checklist for the situation they are experiencing.

The objective of this assessment is to analyze the alerts and other flight deck effects that occurred in the accident and the response expected from the flight crew to see if there is strong support from the interface or if the flight crew needs to find its way to an appropriate response on its own. In one analysis of an operational event, it was determined that the pilot needed to take an action that was the opposite of the training standard. Thus, the assessment tool can aid investigators in understanding why the flight crew did not take the appropriate actions.

Using an influence diagram (William Bramble)

A challenge that multidisciplinary teams face when investigating aircraft accidents is the development of a shared mental model of possible causal influences. Individuals with different backgrounds gravitate toward different issues. Lacking a common accident model, investigations can become fragmented, and the synergistic benefits of a multidisciplinary team can be lost. Since 2014, I have been experimenting with solutions to this problem. The work of Rasmussen (1997) and Leveson (2004, 2011) has been particularly
Both authors have created rubrics for visualizing causal influences, including management and regulatory aspects, and these visualizations can be customized to highlight the unique complexities of a particular accident and industry.

Both authors have strived to create control-theoretic models of sociotechnical systems. They suggest that participants in such systems strive to cope with competitive pressures for productivity and efficiency while simultaneously keeping other aspects of system operation, like safety, within acceptable parameters. Rasmussen asserts that individuals at different levels of the system have different goals, different access to information, and different methods of control, and that the interaction among these actors—government officials, regulators, associations, companies, managers, and operators—sets the stage for an accident. I am not the first investigator to use these models for the analysis of accident causation, but I am the first investigator at my agency to use adaptations of them to facilitate multidisciplinary investigative teamwork.

My initial attempts at influence diagramming did not hew closely to Rasmussen or Leveson. I first tried influence diagramming during my work on the investigation of the 2013 accident involving Asiana Airlines Flight 214 in San Francisco, California, USA, in which the flight crew lost awareness of the active modes driving the autoflight system on approach, and the airplane decelerated below approach speed and struck a seawall. This was a test case for me, and I used influence diagramming to explain investigative analysis that had already been completed. I found a single-page visual representation of complex causal influences underlying this accident to be very helpful for explaining the causal logic of the report, and I used the diagram to present HF in the case at various conferences.

I created another influence diagram during my work on the investigation of a 2014 accident involving a privately operated Gulfstream G-IV that crashed during an attempted takeoff with the gust lock engaged. This time, I did the diagramming earlier in the investigation, and I found it useful for explaining my analysis to other colleagues. I found the technique helpful for explaining my logic in group meetings. This case was also a test of the value of influence diagramming in a less complex investigation. Although the case involved a general aviation airplane operated by two full-time pilots with little management structure, diagramming causal influences allowed me to explicitly link social issues, like procedural drift and distant failures in prior safety audits and certification of a fail-safe design feature, to the sequence of events leading to the crash.

I used influence diagramming a third time during my work on a small-team
investigation of an air tour accident involving a de Havilland DHC-3 that crashed when transiting a mountainous area in low-visibility weather conditions near Ketchikan, Alaska, USA (see Figure 1, page 7). By this time, I had become aware of Rasmussen's acci-map method, and it influenced my decisions about what to include in the diagram. I also began the diagramming much earlier in the investigative process and used the resulting products to lead small-group meetings near the beginning of the analysis phase of the investigation. Use of the diagrams was quite helpful conceptually for linking competitive pressures and social and technical influences to the accident sequence of events. It was also pragmatically useful for aiding the development of team thinking about causal influences and for facilitating team decision-making about which influences to address with safety recommendations and how to divide the work of developing those recommendations.

Since completing the Ketchikan accident investigation, I have been using influence diagramming for two additional investigations that are still ongoing. In these most recent cases, I have been supplementing acci-map–inspired diagrams, like the one shown in Figure 1, with diagrams of organizational control structure, like those developed by Leveson and applied by Thomas and Malmquist in the aviation domain. In my latest investigation, I created a draft influence diagram within weeks of the accident. This facilitated the development of team thinking about investigative issues, facilitated investigative planning, and helped me refine the focus of investigative interviews. In short, I have found influence diagrams to be a very useful tool.

The acci-map–inspired diagrams I have been using have several potential shortcomings. They incorporate a linear sequence of events (as shown in Figure 1) that has been opposed by various theorists, including Leveson. They contain an eclectic mix of content with a less formal hierarchy than those described by Rasmussen. The relationship between influence and outcome is not quantified, and the linkage of evidence to conclusion is not as explicit as the method described by the ATSB (although this linkage is addressed in subsequent written analyses). Furthermore, considerable subjective judgment is involved in the selection of issues to highlight.

Despite these potential shortcomings, I have found influence diagramming quite helpful because it encourages a systems-oriented approach, facilitates the development of a shared mental model among investigative team members, supports team decision-making, and explicitly links safety issue areas with accident features.

Maximizing safety benefit from available information (Joel Morley)
A safety investigation should lead to a reduction in risk. Achieving this objective requires that a safety investigation provides an in-depth understanding of not only what happened at the time of the occurrence, but also why it happened so that mitigations can be directed at the system level. The challenge for the HF investigation is thus: “How do we get to an explanation of human behavior that is rigorous, defensible, and leads us to mitigations that improve safety by addressing the reasons for the behavior at the system level?”

An in-depth investigation that digs into systemic causes is not practicable for every accident. Accidents in less complex systems, or that present lower levels of risk to the traveling public, do not attract the same level of investigation and may not have sufficient data available to provide answers that would lead to systemic changes. More complex accidents, involving greater risk to the traveling public, normally result in thorough investigations and have sufficient data available to support in-depth safety analysis.

The goal is to balance the level of investigation with the data available to get the biggest safety payoff possible (see Figure 2). In this way, we keep the scope of the “not much data” accidents smaller but do enough so that we can use the aggregate to achieve meaningful safety information (e.g., another VFR into IMC accident is unlikely to lead to much safety action but, when considered as part of a dataset, can lead to meaningful inquiries). In accidents where we have good data, we devote greater resources and achieve safety action at the system level.

How do we make sure we are eking every bit of safety benefit from the information we have available? Experience points to five critical success factors related to how we carry out an investigation:
1. Follow a method.
2. Back up your method with tools and frameworks.
3. Use a team.
4. Iterate.
5. Consider the whole system.

1. Follow a method
An investigation methodology that is based on good safety science will save time and make conclusions more defensible by
- providing a structure for organizing data that is based on a firm understanding of safety, risk, and how accidents happen.
- helping to share information among team members.
- making analysis visible to all team members.
- providing a mechanism to challenge the investigation team’s thinking.
At the TSB, we follow our Integrated Safety Investigation Methodology (ISIM). This methodology incorporates steps that guide investigators from the facts of the occurrence to making a compelling argument for mitigations that address system safety deficiencies. Steps include developing a sequence of events, identifying the unsafe conditions and underlying factors that contributed to these events, performing an analysis of the defenses that are already in place to address these conditions, and determining the residual level of risk in the transportation system.

2. Back up your method with tools and frameworks
Of course, any methodology is only as good as the information that is entered into it. We need complementary tools and frameworks to help guide our thinking as we apply a methodology with a view to understanding behavior in complex systems.

At the TSB, we have adopted certain frameworks to help us explain human behavior. For example, we train our investigators to apply a version of Reason’s Generic Error Modeling System (GEMS) to analyze the unsafe acts involved in an occurrence. Applying this model involves examining whether events went according to an operator’s plan and pinpointing the type of error we are trying to explain.

This understanding facilitates the identification of contributing factors and allows safety action to be better targeted on the systemic deficiencies contributing to human performance. For example, understanding that an execution error consisted of a memory failure leads us to examine the effectiveness and use of memory aids. Similarly, understanding that an operator’s plan was based on an incorrect understanding of the operational situation leads us to examine the information available to the operator and the many factors influencing the operator’s ability to perceive and process that information.

We have also developed guides to be applied to help investigate specific areas, including sleep-related fatigue and organizational and management factors. These tools help us to gather and analyze data in these areas, helping to ensure conclusions are rigorous and defensible.

3. Use a team
Perspective-taking, the ability to understand how the situation was understood by those involved as it unfolded, is critical to an effective HF investigation. To understand how to prevent recurrence, we must first understand why the actions of those involved in the occurrence made sense to them at the time. This is best achieved with investigation teams that incorporate different perspectives to challenge viewpoints and expand thinking.

As we work through our analysis methodology and apply the tools and frameworks, it is vital that we challenge our thinking. Explaining the links between the facts of the occurrences and identified underlying factors prompts questions and helps to point out gaps in our knowledge and logic. On large investigations this is easy—the group structure ensures a ‘team approach’. In smaller investigations, when working more independently, we often need to seek out people, and the best investigators do this by pursuing collaborators at critical points in the investigation and talking through their analysis.

In short, a team helps us to build more compelling arguments for safety improvements.

4. Iterate
We are in the business of analyzing complex systems and developing a compelling argument for safety improvements. To do this successfully, we need to build our understanding, challenge it, improve upon it, and build it some more.

Repeated iteration provides us the means to avoid two potential pitfalls in the HF investigation. First, it prevents us from settling too early on an overly simplistic explanation and helps ensure that we are understanding human performance in the context of the system that contributed to that performance. Second, it helps us consider alternatives when we cannot definitively identify a single chain of events. In such cases, we need to lay out the possibilities with the information available to support or refute each one.

When laid out on paper, an investigation methodology looks like a linear process—from data collection to analysis to investigation report. In reality, however, these phases overlap considerably. Analyzing what went wrong in a complex system often leads to additional questions resulting in renewed data collection. For example, hypothesizing that a knowledge deficiency contributed to a particular crew action leads an investigation team to begin to review training programs and files that may lead to further data collection to establish whether the issue is local or systemic. This cycle of scratching the surface and then digging deeper into a specific issue takes place multiple times when carrying out an HF investigation.

5. Consider the whole system
Finally, to be sure we achieve the greatest safety benefit from an investigation, we need to consider all aspects of the system, including organizational factors, the regulatory framework, and regulatory oversight. The investigation should be considered complete when we reach an underlying factor for which no further mitigation is practicable.

Using a specific occurrence analysis methodology (Fanny Rome)
The aim of safety analyses is to understand why there are occurrences and draw up recommendations to prevent their reoccurrence. These two objectives

The activity or the process is represented by a ball rolling along a gutter.

Its trajectory is not linear as disruptions always exist in daily operations. The ball is normally contained in the gutter.

One disruption or several disruptions combining together can be strong enough to force the ball out of the gutter. This corresponds to the escape point, where the control of the situation is lost.

The situation can be recovered within a time period. If this does not happen, an accident occurs.
The sociotechnical system is supposed to work safely. Safety performance; i.e., how the sociotechnical system is supposed to keep the system safe in any situation, performance variability. Data come from the occurrence but also from everyday working practices and from similar occurrences. Indeed, it is interesting to consider the performance of the safety principles on other days. This might reveal that the adjustments are everyday adjustments that are not specific to the day of the occurrence or to the different operators others worked. The methodology does not focus on errors but rather on performance variability. Data come from the occurrence but also from everyday working practices and from similar occurrences.

Lessons learned: The lessons learned raise two kinds of questions: (1) What can be inferred concerning the safety principles’ effectiveness and robustness? (2) Were the expectations realistic? These elements then guide the safety recommendations.

An example
We applied this methodology to the analysis of a serious incident: a near collision between an aircraft in visual approach and a helicopter in VFR flight.

Rather than considering the performance of each actor individually, we considered the overall situation, the “approach toward parallel runways with VFR and IFR traffic.” The potential accident was a mid-air collision, and the escape point was the aircraft following conflicting flight paths without anyone being aware of it. Safety principles were determined by answering the question, “What was supposed to keep the system safe in ap-
approach with mixed traffic?” For example, the visual acquisition of traffic by crews is based on an outside visual scan guided by ATC information, on the monitoring of the VHF frequency, and on the ND, which is an unintended use of TCAS. The controller’s awareness of the traffic is based on the radar, on communications, on the outside visual scan for the tower controller, and on reported positions from the crews.

To recover from a loss of separation, the detection is supported by alerts: TCAS may alert the crews of the conflict and the controller might be informed by the STCA.

The performance of these different principles was analyzed. The weakness of the visual detection was underlined once more. A single technical failure (the transponder failure) led to the failure of several safety principles. The technical failure the day of the occurrence entered in resonance with performance variability (nonstandard phraseology, variability in flight paths, etc.). The impact of the loss of the transponder was clearly underestimated.

The occurrence showed that at an airport with high-density traffic, the wish to optimize the traffic and keep it flowing, in addition to the trust existing between pilots at their home base and controllers, could make these actors work with reduced safety margins without being aware of this. This leads to a system that is not very robust to a disruption.

In conclusion, in this methodology, human performance is not considered in an isolated way but rather at a sociotechnical level. Performance is considered in light of safety—safety investigations are not audits or training evaluations. Performance is considered in light of daily habits and constraints, and over time. By doing so, the methodology helps us to draw up recommendations that not only focus on the human but also on the systemic level, in particular when the expected human performance is not realistic.

Presentation summary

The starting point for this paper was a recognition that two misconceptions about accident causation still pop up in the popular communications (and sometimes in aviation industry publications):

1. Accidents typically have a single cause.

2. Most accidents and incidents are caused by human error.

We counter these misconceptions with an understanding that accidents are the result of some combination of latent failures, unexpected situations or failures, underlying organizational policies and practices, degraded environmental conditions, and the actions of pilots, maintenance technicians, and controllers. We consider it naive and unhelpful to conclude that an accident was the result of a single cause, especially if that single cause is a human.

Yes, human performance contributes—in the majority of cases—to the sequence of events that lead to an accident, but unless we clearly understand the factors influencing human performance in an occurrence, resulting safety action will be poorly targeted or superficial. To best identify and manage system risks, we would prefer to see the identification of human error as a starting point for analysis, not an end point. Collectively, we—the four authors—have been conducting human performance investigations for decades, and we have developed (or are aware of) analysis methods and tools to aid in revealing systemic influences on human performance.

We each described investigation techniques, processes, models, or tools that can provide a link between human performance and systemic influences. These together do not represent a single, coherent analysis approach but are meant to show that promising solutions exist for specific performance issues or for conducting an investigation. A larger point is that HF expertise should be sought out to support any investigation.

One difference that may stand out in our descriptions is between analysis that is triggered by a human error and analysis that begins with an undesired system outcome. In the first approach—e.g., Morley’s GEMS method—the analysis starts with a specific behavior that is different from the behavior expected (typically having the benefit of hindsight)—a pilot does not detect that airspeed has decreased to the stickshaker or a pilot makes an input on the controller (column or sidestick) that is the opposite of what was prescribed. These unexpected behaviors (in the operational context) are typically labeled as human error, and there follows an attempt to understand the nature of the error and what led to it. Note that these errors may not be linked to an undesired outcome, such as a low-energy state or an incorrect altitude.

The second approach, described by Rome, starts with an undesired outcome: a loss of control of the system. The analysis then identifies the ways in which the overall system design was supposed to prevent or recover that loss of control; these are the safety principles. The analysis next attempts to determine how the safety principles failed to prevent system performance from transitioning to the undesired outcome. For human performance, specifically, “How did the system fail to maintain (or succeed in maintaining) performance within expected limits?” The CREW tool, discussed by Mumaw, can be useful for understanding why some safety principles fail to achieve the desired human performance; it offers a systematic analysis of the flight deck effects—indications, alerts, etc.—to identify the ways in which they can reduce pilot reliability.

These two complementary approaches reflect

- the variability (or lack of reliability) of human performance that is always present and is either managed or it leads to more vulnerable system states—or even undesired outcomes.
- the system design (broadly defined, e.g., by the flight deck interface, operational procedures, pilot training, oversight from others, etc.) that, ideally, manages that performance variability to ensure safe mission completion.

The appropriate role of the overall aviation system is to both increase reliability in human performance (reduce human errors) and to manage the inevitable performance variability when it threatens to transition to an undesired outcome. An investigation of human performance is likely to address both perspectives in explaining systemic influences, and Bramble offers representational methods to integrate these influences into a more coherent description.

We see a future in which these human performance investigation methods and tools are important elements of a more integrated approach to accident investigations. Each investigation agency is on its own path to this more integrated approach, and we hope that this paper has created a spark for further progress down that path.
The event synopsis
On Saturday, Oct. 31, 2015, at 0350 UTC, an A321 registered EI-ETJ departed from Sharm El-Sheikh, Egypt, under flight number 7K-9268 to St. Petersburg, Russia, with two cockpit crewmembers, five cabin crewmembers, and 217 passengers on board. At 0412 UTC, the aircraft vanished from radar. Aircraft wreckage was found in central Sinai (about 131 nautical miles north of Sharm El Sheikh city). The aircraft was completely destroyed, and there were no survivors. The aircraft debris field was spread over more than 16 kilometers southeast of the main wreckage area, typical of an in-flight breakup.

Airbus crisis response
Airbus Toulouse Crisis Control Center was immediately activated, and contact was made with Le Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile (BEA), airline representatives, and the investigator-in-charge (IIC) from the Egyptian Central Directorate of Aircraft Accident Investigation (ECAA) leading the investigation. The IIC accredited representatives from all the countries involved included:
• Russia (Interstate Aviation Committee/IAC MAK) as the state of the operator,
• France (BEA) as the state of design,
• Germany (Bundesstelle für Flugunfalluntersuchung/BFU) as the state of manufacture,
• Ireland (Air Accident Investigation Unit/AIU) as the state of registration, and
• The United States (National Transportation Safety Board/NTSB) as the state of the engine manufacture.

The operator was appointed technical advisor to the ECAA. Pratt & Whitney was appointed technical advisor to the NTSB. EASA and Airbus were appointed technical advisor to the BEA.

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Mission preparation
First information shared by the IIC revealed that the accident site was isolated, spread over several kilometers, and only accessible by helicopter (one and a half hours and 280 kilometers away) with daily rotations from dawn to dusk. This would limit the time available on site and would require several coordinated teams. Both recorders had been located and were being recovered so a separate team was set up to prepare data retrieval in the Cairo facilities.

The Airbus chief product safety officer’s decision to dispatch a go-team is always made after information consolidation from multiple sources (local field representatives, embassy, news media, etc.), medical checks of team members, and a security assessment as appropriate.

The Airbus go-team arrived in Cairo, Egypt, on November 1. The team was composed of an Airbus product safety accident investigator who was assisted by two corporate security officers and specialists from powerplant, aircraft systems, and structure. This team was then reinforced by four additional members from product safety, flight test, and flight recorders to support flight data recorder analysis.

Mission preparation and coordination
As the time on site was limited, the objective was to maximize efficiency by splitting the teams into groups:
• The first group would detail the “main” wreckage (see Figure 1, page 15) formed by the forward fuselage up to the wings and both engines (separated from the wings).
• The second group would focus on the rather large fuselage parts present a few kilometers away from the main wreckage site.
• The third group would try to reach the most remote light aircraft parts.

Each group was composed of representatives from each organization. As there is no GSM network cell coverage in that area, iridium phones and walkie-talkies were used to ensure coordination and communication between the groups.

Before each group separated, an initial risk assessment and awareness was proposed by the operator and Airbus and validated by the IIC.

Initial risk assessment
The operator and manufacturer can provide relevant information to the investigation boards concerning potentially dangerous cargo, estimated fuel at the time of impact, and location, as well as the number of oxygen bottles, fire extinguishers, oil tanks, composite materials, batteries, and more (see Figure 2, page 15). All of these elements must be carefully considered before approaching a damaged aircraft.

Because the area to cover in the desert was immense and there was limited time on site, each group was requested to gather only factual information while...
keeping analysis and identification for a later stage. Each group recorded wreckage evidence by taking the GPS position and photos of each part. Upon return to ECAA headquarters, the information collected was shared with all members of the investigation, and the missions for the next days were prepared.

Next missions
Viewing the accident site configuration—spread over several kilometers—it appeared that the initial event occurred at a rather high altitude and that the first parts to detach were the furthest ones from the main wreckage. Airbus Defense and Space shared “Pleiades,” very high resolution imagery, to help the team locate wreckage parts and prepare for missions.

In the desert, travel is permitted only by four-wheel drive vehicles so that the topography is not damaged and by following “wadi” (a valley or ravine) protected by Egyptian military forces (ground and air). Groups were then split up according to areas that could be reached following predetermined routes (see Figure 3, page 15). This would keep the groups from having to search for route access, avoiding long detours and saving time.

Evidence collection, engineering analysis
Due to the very large number of wreckage parts and evidence collected, Airbus set up a “mirror” team coordinated from Toulouse Crisis Control Center composed of experts to analyze collected data that were transferred overnight from Cairo on a secured server. From the collected photos and on-site observations, the team precisely identified aircraft parts and performed an in-depth analysis of high lift and fuel systems, doors and exits, the powerplant, and the airframe structure and then transmitted the results of their review to Cairo’s team.

On the systems side, this helped to rule out some scenarios and helped the on-site team focus on the remaining ones.

On the structure side, for each aircraft part, they could identify and locate it precisely on the airplane.

While performing the identification, the team drew the contour of each part on a spreadsheet by counting its frames and stringers. This provided a global vision of what was recovered, what was still missing, and what parts were adjacent to other parts.

Aircraft 3-D mockup
The 3-D mockup of the aircraft airframe and systems was created using CATIA software, which is usually used for design and production purposes. It is composed of several layers; the idea here was to adapt the software from its original purpose and use it to create a 3-D reconstruction of the wreckage. The 2-D drawings were redrawn on the external layer (as if it were decals) and applied to the airframe layer to display each part precisely (see Figure 4, page 15).

Then one by one, each wreckage part was placed on the mockup. Parts with a common side matched very well, and it appeared that more than 95 percent of the aircraft could be reconstructed.

This 3-D visualization allowed the team to identify areas of particular interest to the investigation and helped determine where the event initiated (see Figure 5, page 15).

Wreckage layout
In order for the metallurgist and structure specialists to further investigate the parts located in those areas and to analyze the interfaces between them, the investigation team decided to gather all the wreckage parts from the

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was appointed director of flight safety–accident/incident investigations in 2006 within the Airbus product safety team. In this function, he leads Airbus investigations of major events in support of official investigation board activities. In his current position, Bardou has developed expertise in the accident investigation domain by coordinating the Airbus team’s multiple on-site activities, flight data recorder analyses and associated engineering studies, and operational reviews, thus addressing the safety issues and capturing the lessons learned. Prior to assuming this position, he served six years in the Flight Test Department for in-service and development of aircraft flight test analysis.

(Adapted with permission from the author’s technical paper Airbus Support to Accident Investigation presented during ISASI 2017, Aug. 22–24, 2017, in San Diego, California, USA. The theme for ISASI 2017 was “Do Safety Investigations Make a Difference?” The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)
desert and perform a wreckage surface layout reconstruction (see Figure 6, page 15).

The ECAA managed to transport every part associated with the accident from the desert to an area close to Cairo International Airport using exceptional means and convoy.

Before starting this "giant jigsaw puzzle," a work process was proposed by Airbus and agreed to by all the parties. A fuselage can be represented as a cylinder composed of circular frames and longitudinal stringers. If this cylinder is split open from its top and rolled over, it would end up in a 2-D grid in which frames and stringers references could be used as coordinates to locate every part (see Figure 7, page 15).

Given the size and weight of certain parts and the limited space for the cranes and lift forks to maneuver, the order in which each part was put on the grid was of key importance. We used a whiteboard to draw the grid and label each part (see Figure 8, page 15) and agreed on how to proceed before moving any heavy part.

This grid was painted on the floor (see Figure 9, page 15) to reproduce what was planned on the whiteboard.

When the plan was agreed to by all the parties and presented to the drivers, we were able to start positioning each part at its correct location.

Thanks to the preparation work and advanced discussions with all the involved parties and the exceptional dexterity of the Egyptian drivers, the wreckage surface layout was completed in only a couple of days (see Figure 10, page 15).

Once this was performed, the investigation team had a global view of the aircraft wreckage and focused on particular areas of interest. Metallurgists and structure specialists were not only able to examine fracture surfaces and lines propagation but also to compare those to adjacent ones. From this, they were able to identify parts that needed to be sent to the laboratory for further investigation.

Conclusion

Airbus support to this particular accident investigation was continuously provided to the investigation boards throughout all phases of the investigation. By sharing its resources and expertise, Airbus provided on-site support for security and risk assessment by dispatching a team of experienced investigators and specialists. It also provided its expertise and support in mission planning and wreckage identification using all available resources globally within the Airbus company.

Airbus support to the investigation was not limited to on-site investigations but was backed up by teams of experts coordinated from Toulouse Crisis Control Center that worked in conjunction with the field investigation to multiply efficiency and ensure proper reactivity.

Airbus proposed the use of the best adapted tools and resources that could support the investigation and created new ways of using them. This allowed investigators to perform a complete mapping and identification of a wreckage spread over 16 kilometers in the desert and to assist the investigation team to complete 3-D wreckage reconstruction and physical layout less than one year after the accident.

Metallurgists and structure specialists were able to determine the in-flight breakup point of initiation and send structure samples to laboratories for root-cause analysis.

From the top left:

Figure 1. Russian television footage.

Figure 2. Airbus aircraft rescue and firefighting chart.

Figure 3. Area determination from Google Earth.

Figure 4. From wreckage photo to contour drawing and 3-D modeling.

Figure 5. 3-D mockup visualization of identified wreckage parts.

Figure 6. Wreckage parts gathered from the Sinai desert.

Figure 7. A representation of the fuselage split open.

Figure 8. Parts location using a grid on the whiteboard.

Figure 9. Grid painted on the floor.

Figure 10. Wreckage surface layout in progress.
ACCIDENT REPORTS AND AERONAUTICAL DECISION-MAKING: APPLYING CASE-BASED REASONING TO IMPROVE GA SAFETY

By Ross Rozanski
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While the fatal accident rate for commercial aviation has been steadily decreasing over past years, the rate for general aviation (GA) has remained largely the same. Although the implementation of concepts like crew resource management (CRM) and aeronautical decision-making (ADM) has been linked to reducing many commercial accidents, a gap between teaching this knowledge and its successful implementation remains in GA. By successfully applying these concepts in GA, one of the most attributed causes of GA accidents—pilot error—can be mitigated.

ADM is currently taught with the methodology of rule-based reasoning (RBR), which emphasizes learning objectives in a theoretical and academic framework. Research shows that mixing this methodology with case-based reasoning (CBR) produces safer pilots more capable of reacting to emergency scenarios. Consequently, investigators are called on to prepare more thorough accident reports that can be used with CBR in pilot training, and members of the aviation community are called on to encourage the use of CBR in pilot training to increase GA safety.

The fatal accident rate in GA has been constant in past decades, with about 300 fatal accidents each year since 2004. This alarming statistic is indicative of a consistent problem in GA safety that has yet to be addressed—namely pilot error and loss of control of the aircraft, the most frequent causes of GA accidents. While these issues have been mostly resolved in commercial aviation with the implementation of CRM, the application of this concept in ADM and single-pilot resource management has not yielded a similar decline in fatal accidents.

One reason is experience—the decision-making processes of expert pilots is qualitatively better than those of novice or intermediate pilots. Specifically, those with more-experienced backgrounds demonstrated "a qualitative distinction... in the process of information acquisition and not simply in terms of the quantity of information accessed." The ability to perform both of these tasks is evident in many fields in which experts are best able to diagnose a problem by integrating the relevant factors. Although there is no substitute for pure flight hours, a way to increase the task assessment skills of less-seasoned pilots is to encourage critical assessment of their own performance, providing access to simulated scenarios, and reflection of case studies.

CBR is, in the most general sense, "the act of developing solutions to unsolved problems based on preexisting solutions of a similar nature." Through the process of retrieval, analogy, adaption, and learning, individuals can systematically respond to a scenario with a degree of experience, even if they have never physically experienced the actual situation before. As a learning model, there are several benefits to CBR, including the ability to learn incrementally, the notion of adaption, a focus on failure as a learn-
ing experience, and taking advantage of the problem-solving information processing intrinsic to human cognition.

Although research has proved the advantages of learning with CBR in fields as diverse as medicine and law, only recently has this been studied in pilot training. Several studies using both pilots and nonpilots have demonstrated that reflection on others’ experiences, training that includes CBR with RBR, and recall of critical flight events have produced pilots with more expert decision-making skills. Specific examples of this include “case-based remindings play an important role in expert pilot decision-making” and “participants who reflected on a set of cases involving pilots flying into adverse weather conditions were more likely to follow the VFR rules for minimum visibility in a simulated flight than participants who simply completed a free recall task.”

In the context of GA pilot training, CBR and reflective practice enable students to achieve higher correlation between theory and practice and to better identify how they learn in order to apply past problems/failures to future actions. But despite the mounting evidence that the learning methodology of CBR and reflective reasoning creates safer pilots, it contrasts with the methodology used in pilot training and the teaching of ADM currently in use.

The current approach to GA pilot training, specifically ADM and methods aimed to address pilot error, can be significantly improved by the utilization of CBR, with the aim of achieving its benefits. The traditional way to teach ADM differs greatly from how pilots make decisions in the real world. ADM historically has been taught as a rulebook to follow, a concept that seeks to instruct principles broken down into chapters that should be considered when acting as pilot-in-command. Many of the situations pilots experience, however, do not have clear goals or well-defined alternatives but rather possess an inherent “fuzziness.” Situations with such vague and undefined options are best suited for determination of overall similarity, opposed to an exact search. Literature suggests multiple ways to incorporate CBR and reflective reasoning into current training practices. Taking care never to curtail debriefings, using a reflective journal, and self-describing maneuvers and tasks facilitate these practices.

But without giving students an unrealistically large amount of direct physical experience, the best way to implement CBR is with case studies. For student pilots, this includes scenarios regarding how low to fly, if and how to avoid adverse weather, and others in which a decisive choice must be made after analyzing many variables. These case studies are intended to provide a framework for theoretical concepts with practical examples that include many real-world instances that can be used in ADM.

A case that could be particularly effective if used for ADM purposes is the accident of a Cessna 441 on July 16, 2008 (NTSB Number: SEA08FA161). As the private pilot was touching down at Sunriver Resort Airport, the aircraft bounced on and off the runway several times with increasing amplitude. Instead of choosing to go around at this point, the pilot committed; and on the last bounce, the propeller made contact with the runway. The pilot lost control and was killed. This case has several details that make it a superb example for CBR training. One is that the pilot experienced a challenge that many pilots face—having difficulty with touchdown. Another is that a definitive judgment call had to be made based on indefinite information: how many failed attempts are too many before deciding to go around? And another is the severe consequences of poor decision-making, in this case the death of the pilot.

The NTSB report cites probable cause as misjudged landing flare and improper recovery, but for ADM purposes this could be improved upon by also stating that any flare with bounces of increasing height should be aborted. Such cases can serve to demonstrate valuable lessons in very real contexts, and therefore focusing on the investigations of such cases and the implementation of the reports should be encouraged in GA training.

For the purposes of ADM, such case studies can be improved. Because humans tend to better recall events with effective details, it is recommended that the case studies used for ADM strongly engage the reader with specific and emotional details that may seem irrelevant in current reports. These details are nontechnical but add to the memorability of a given scenario, therefore becoming more effective for ADM purposes. There are three objectives investigators should set in order to im-
prove CBR for GA pilot training: 1.) Provide GA accident reports that give a recommendation similar to commercial reports, 2.) Consider a pilot’s CBR background while conducting investigations, and 3.) Give non-fatal accidents greater detail.

Commercial aviation accident reports often have recommendations to address errors with the goal of avoiding them in the future. But due to a multitude of factors, GA accidents rarely get the same focus, often providing a summary with many open questions for the common pilot. While the reports themselves can prove valuable for learning the consequences of poor ADM, a definitive recommendation at the end can significantly increase a report’s learning value. In addition, accident causes can be more readily identified by taking into account contextual details previously unconsidered, specifically one’s case-based background.

Although an accident can be attributed to incorrect individual pilot inputs, an evaluation of a pilot’s history with the given scenario can shed light on why those errors occurred. For example, going off the end of a short runway can be directly attributed to many factors. But any of those factors could have occurred because of lack of experience landing at short runways. Therefore, specific factors could be encouraged to consider specifically for pilots new to that situation.

Overall, particular caution can be recommended when entering these situations as a novice, therefore providing more insight into a crash than simply a pilot’s fallibility. Nonfatal accidents should not receive less study and analysis because nobody died. Anybody in a high-risk field can describe “near miss” situations in which a disastrous result was avoided by a small margin. Two events can have equally valuable lessons to learn even if their outcomes are wildly different. Neglecting nonfatal accidents can mean neglecting relevant and beneficial insights. It would be unreasonable to declare that every aviation accident be met with the same rigor and resources as some of the largest incidents, and thus it is encouraged that priority be given based on the occurrence rate of similar accidents and the potential for fatal outcomes.◆

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Investigations are the cornerstone of the superb safety record that aviation safety enjoys. The aviation safety process is the envy of many other disciplines, and its reputation is well earned. The investigation process has evolved over the years from a reactive one that looked at one accident at a time to a proactive one that looked at multiple cause factors of multiple accidents. Today, there is a drive toward a predictive process that looks at accident, incident, and normal operational data to determine areas to reduce risk. The investigation process has thus grown from spot fixes to area fixes to system fixes.

Today, investigations help create or strengthen safety nets that further reduce risk. A safety net may be a single element or a collection of elements, all designed to reduce risk by reducing the probability or severity of a specific hazard. There are actually two levels of safety nets. Tier two safety nets are used in the design, manufacturing, and certification of aircraft and their components. Tier one safety nets are safety nets that frontline aviation organizations utilize in day-to-day operations.

“SAFETY NETS ARE CREATED BY EVERY LEVEL OF THE AVIATION SPECTRUM, INCLUDING MANUFACTURERS, OPERATORS, AIRPORTS, ATC, AND REGULATORS.”
Safety net elements are normally the result of recommendations made by accident or incident investigations. The elements of a safety net can be active or passive. They can be physical elements, technological elements, procedural elements, or training elements. Some examples of the various types of safety net elements are a guard on a critical switch (physical), TCAS (traffic collision avoidance system) (technological), stabilized approach criteria (procedural), and upset prevention and recovery training (training). Safety nets are created by every level of the aviation spectrum, including manufacturers, operators, airports, ATC, and regulators. As an example, a safety net addressing the CFIT (controlled flight into terrain) challenge has elements such as TAWS (terrain awareness warning system), MSAW (minimum safe altitude warning), constant angle approaches, stabilized approach criteria, and the design of approaches.

The number of accidents each year is consistently decreasing, which is good news. At the same time, the availability of operational (nonaccident) data is increasing. Because of this, investigators need to consider what is next for investigations. What is needed is a change of paradigm. We now have the data to look at events, both significant and normal, to identify hazards and determine the risk-reduction potential of proposed safety net elements without having an accident. However, the current safety system focuses on negative outcomes (i.e., an outcome resulting in damage or injuries), not events. It’s outcome-based. For example, the Air France 447 accident investigation revealed several almost identical events. However, the previous events had no negative outcome, and thus they were just part of the data. In the case of the Lexington wrong-runway departure accident, initially it seemed to be a very unique accident. However, in reviewing the data it was discovered that several very similar events had occurred. Since none of the previous events had a negative outcome, they were again just part of the data set. Some disciplines, like security, don’t require a negative outcome to act (think shoes, liquids, belts, etc.). To be effective and to continue the tradition of investigation excellence, investigators need to utilize the availability of operational data and shift from just negative outcome–based investigations to include event-based investigations.

Investigations will continue to be the backbone of reducing risk by identifying new safety net elements or exposing holes in existing safety nets. The more investigators analyze operational data, the better the safety nets investigations will create. The difference is that previously we learned from accidents and other negative-outcome events. In the future, we can learn from operational data. As an example, consider the fatal accident in Bedford, Massachusetts, USA, in 2014. A corporate Gulfstream IV suffered a takeoff accident caused by a late rejected takeoff (RTO).
The reason for the RTO was that the aircraft wouldn’t rotate for takeoff because the controls were locked. The controls were locked because the gust lock was engaged. A review of the aircraft’s data showed that no control check, which would have detected the engaged gust lock, had been conducted prior to takeoff. In fact, the data revealed that the accident crew had performed a pretakeoff control check on only two of the previous 176 flights. There was no negative outcome for 173 of those flights.

Now, no control check is not a caution, a warning, or an exceedance, and it normally has no negative outcome, so it’s unlikely that it would be noticed in a normal analysis of the aircraft’s data. However, in comparing this aircraft’s data to pretakeoff operational data from thousands of flights, not conducting a pretakeoff control check would have shown up as a difference. This is an example of how operational data can be used to identify potential problem areas (e.g., no control check) before they end up as a negative-outcome event.

However, creating and strengthening safety nets using operational data, although vital and necessary, may not be the primary way to reduce risk in the future. Over the past 20 years, there have been 358 commercial jet major accidents. Two stand out as ones that didn’t have an associated first-tier safety net that could have prevented them (TWA 800 and BA 038). There are probably more, but in general it’s very rare to have a major accident today that has no associated first-tier safety net that could have prevented it.

So in addition to building and enhancing safety nets, future investigations need to also identify and address the gap between existing safety nets and implementing those safety nets. Accidents happen in those gaps. These gaps exist today, but they’re normally only found as the result of an investigation of an accident or other negative-outcome event. Future safety investigations will hopefully be able to identify these gaps by using normal operational data and not necessarily just negative-outcome events. We have the data now to identify these critical gaps through investigations of normal operational data, and we don’t need the proverbial smoking hole. In fact, we can use the data to prevent the smoking hole.

As the result of outstanding instigations, today we have superb safety nets and the accident record to prove it. However, we continue to have accidents—accidents that we have safety nets designed to prevent. There’s a gap between having safety nets and using safety nets. We need to fill that gap. Some potential ways to address this safety net gap challenge are technology and, as a last resort, regulation. We need to start identifying the gaps between creating and using safety nets, and we need to start using operational, nonnegative-outcome events to do that. With the current and growing availability of data, we can do that.

In any case, we need to mind the gap. ♠
INVESTIGATIONS, RECOMMENDATIONS, AND SAFETY MANAGEMENT SYSTEMS

By Thomas A. Farrier, Senior Safety Analyst, JMA Solutions, LLC

Current perspectives on safety management systems (SMS) vary widely from one country to the next, especially with respect to how they are used in the aviation domain. The International Civil Aviation Organization (ICAO) performed a valuable service to the worldwide civil aviation community with the publication of the first edition of Document 9859, Safety Management Manual (SMM), in 2006. This landmark document gathered together a host of processes that collectively offered an organized structure within which safety efforts on the part of individual states and other interested parties could be developed. As it stated in its objective (paragraph 1.2): The objective of this manual is to provide states and product and service providers with

- an overview of safety management fundamentals;
- a summary of ICAO safety management standards and recommend practices (SARPs) contained in Annexes 1, 6, 8, 11, 13, and 14;
- guidance on how to develop and implement a state safety program (SSP) in compliance with the relevant ICAO SARPs, including a harmonized regulatory framework for the oversight of product and service providers’ SMS; and
- guidance on SMS development, implementation, and maintenance.

ICAO’s intent in assembling a list of SMS guidelines was to offer a set of management processes that could be adopted by SSPs, not to suggest other preventive activities should be excluded, discounted, or downplayed. However, it has become clear that an unintended outcome of ICAO’s various moves to consolidate guidance on SSPs has been to downplay the role of accident investigations in the SMS environment, or even to disconnect them entirely from other preventive processes. While one would expect SMS to be tightly coupled with and effective in integrating the work of civil aviation authorities (CAAs)—the regulators—and investigative bodies, the trend seems to be for the latter to be discounted as part of the larger preventive process. The question is why is this the case and what should be done to address where it is happening?

For a variety of reasons, SMS and investigations—including the recommendations that result from them—are not always a good fit with each other. Some relate to expectations regarding the ability of an SMS to further improve upon the level of safety achieved in flight operations to date. Others seem to stem from how SMSs are structured and their focus on trying to identify and respond to “precursors” instead of dealing with known issues. In short, many SMSs increasingly are inadequately positioned to incorporate or take action on insights from accident investigations and the recommendations resulting from them.

There are inherent tensions between the respective philosophies embodied by SMS and investigations: a focus on what might happen versus what has happened; a desire to consider hazards in the abstract instead of focusing on concrete experiences of actual loss; and, of course, the downplaying of “reactive” investigations against support for “proactive” management efforts. Accordingly, this paper explores where SMSs and accident investigation processes come into conflict, how this has come to happen, and how their disconnects can be remedied.

The rise of SMS thinking

The history of accident prevention throughout at least the first century of powered flight has been fairly logical, progressively moving forward through a series of sequential and sometimes overlapping objectives:

- Keep aircraft from falling apart or dropping out of the sky.
- Allow them to be operated safely in other than day visual meteorological conditions.
- Require them to be built to protect their occupants in the event things go wrong, and
- Respond to new hazards arising from more and faster aircraft, busier airfields, and efforts to drive greater efficiencies by reducing various historically developed safety margins.

From this has flowed a whole series of philosophies of and taxonomies for safety thinking, all of which have been brought to the table in pursuit of measurable but incremental improvements in the overall safety of the aviation system as a whole. The easy wins are long behind us; the low-hanging fruit has been picked from the trees. Today’s challenges are to find even more opportunities for preventing accidents while trying to avoid adding risk to the system in the quest for greater efficiencies in its operation.

Almost from the days of test flights at Kitty Hawk, North Carolina, USA, it became clear that aviation had to be approached somewhat differently from other outgrowths of the Industrial Revolution simply because it was subject to such novel and poorly understood hazards. Exploring those hazards led to accident investigations assuming primacy in aviation safety efforts, and the ways those investigations were conducted evolved to meet new challenges and different fact-finding requirements. Increasingly organized study of accidents and their causes also led to organi-
One primary objective was standardizing with Document 9859. That document’s ICAO’s efforts in this direction started was needed at an international level. of and approach to civil aviation safety was the focus, not the instrumentalities of safety practices themselves.

Those seeking improvements in aviation safety have long been able to identify and meet safety needs without exerting control over the rest of the organization of which they are a part. The most effective safety organizations have been developed in response to recognized needs, and the best of them always have been created with a mandate from higher up in their companies or governments and with the leadership backing necessary to do their jobs. Analysis of operating hazards (for the purpose of tackling them) occurred side by side with analysis of accidents and incidents; knowledge developed from such analyses found its way to the desks of those best suited to act on it.

Given the above, with clear evidence of organic development and unforced progress toward what have come to be referred to as “safety policy and objectives,” “safety risk management,” and “safety promotion”—as well as the evolution of a formal process of data collection and the making of recommendations leading to action (i.e., “safety assurance”)—the question becomes is an SMS a natural outgrowth and consolidation of effective preventive efforts or was the overarching concept deliberately structured or otherwise obliged to remain limited to a subset of proven preventive strategies and activities?

ICAO’s Annex 19 to the Convention on International Civil Aviation: Safety Management took the form it did because ICAO determined that a unifying theory and approach to civil aviation safety was needed at an international level. ICAO’s efforts in this direction started with Document 9859. That document’s primary objective was standardizing SSPs. The term "safety management system" is not even in its title; the concept itself is not addressed in any detail until Chapter 5. There does not appear to be any deliberate effort to create an overarching SMS, but rather to elaborate on and make certain functions and attributes associated with effective SSPs accessible.

To some extent, the rise of SMSs in their current form coincided with a need to find new ways of dealing with a worrisome slowing in the rate of overall improvement in the aviation safety record. As the raw numbers of airline accidents steadily declined, the even faster growth of airline operations threatened to “make the numbers look bad” despite the occurrences of accidents themselves trending steadily downward. This trend, which was observed at the same time that safety thinking was moving into the so-called “Organizational Era,” made the advent of wide-ranging SMSs virtually inevitable.

Thus, rather than simply offering a notional collection of minimum programmatic requirements for SSPs, aviation-specific SMS became the embodiment of an earnest desire on the part of the aviation safety community to address the most intractable types of aviation accidents: those with outcomes similar to those seen in historical accidents, but at least partially traceable to the added complexities of modern aircraft and the present-day aviation system.

On the other hand, the lineage of SMS—both in aviation and in other domains—is traceable to theories of “quality management,” which long have been proven to be exceptionally effective in production-based activities but of extremely limited value in enterprises in which the emphasis is on the delivery of services. Applying SMS thinking to certain aspects of aviation operations—say, maintenance, ramp operations,

(Adapted with permission from the author’s technical paper entitled Investigations, Recommendations, and Safety Management Systems presented during ISASI 2017, Aug. 22–24, 2017, in San Diego, California, USA. The theme for ISASI 2017 was “Do Safety Investigations Make a Difference?” The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)

Tom Farrier has been a member of ISASI for more than 20 years. He began his aviation safety career as a U.S. Air Force flight safety officer, during which he served as an on-scene investigator as well as performing prevention and programmatic duties at wing, command, and headquarters levels. Since 2005, he has worked as a government contractor on a variety of aerospace safety matters. He currently is the senior safety analyst for JMA Solutions, LLC in Washington, D.C., USA. The views expressed in this paper are his own and do not reflect official positions of JMA Solutions, LLC or its clients.
and employee occupational safety and health—makes perfect sense. Indeed, Paragraph 2.9.2 of Document 9859 notes more than a half-dozen "typical management systems" found in aviation organizations, including

- a quality management system (QMS),
- an SMS,
- a security management system (SeMS),
- an environmental management system (EMS),
- an occupational health and safety management system (OHSMS),
- a financial management system (FMS), and
- a documentation management system (DMS).

Document 9859 even goes so far as to assert that SMS and QMS are "complementary." However, each of these separate management activities tends to operate in isolation instead of cooperatively since each has its own objectives, defined by its relationship to the larger goals of the enterprise. Regardless, the great virtue of anything based on quality thinking is in the consistency of documentation and process it offers. However, the hidden trap is that the limitations of processes themselves constrain what they are equipped to handle to what is known.

The institutionalization of SMS

At this point, a few questions start to suggest themselves.

- Given the stated intent of both Annex 19 and its predecessor document, how did aviation SMS take the shape it has assumed in many civil aviation authorities today?

- Why are at least some ICAO-conforming SMSs so rigidly structured in terms of both components and processes?

- What are SMSs actually expected to do?

Answering these questions is not as easy as one might expect, especially given that ICAO’s initial vision of “safety management” was as a starting point for an overarching SSP, not for the development of SMS as an end unto itself.

The opening paragraphs of Document 9859’s Chapter 5 suggest some of the basic expectations that attend the implementation of an SMS. These emphasize the “proactive” outcomes expected of the SMS process and the prominence of risk management in the overall construct. However, they do not in any way suggest that any specific strategies toward these objectives should be preferable to others. In particular, they do not dismiss any initiatives or sources of data on the basis of their “reactive” natures—the goal is proactive, but the means to that goal are not constrained in any way.

The trouble is that too-rigid SMSs themselves often bring little new to the table while at the same time rejecting some accident prevention practices that have been refined over time—simply because the latter are seen as being “reactive” or otherwise outdated. This is shortsighted at best and self-deluding at worst.

Another driver of the shape SMS began to take was rooted in the safety profession’s long-standing reliance on the Heinrich Pyramid, which suggests it is possible to leverage lower-consequence events for insights into the much smaller cohort of catastrophic occurrences. It is unwise to focus on the former to the exclusion of the latter; preventive medicine is practiced every day, but physicians don’t ignore active bleeding over applying cold packs to bruises. Still, the emphasis on being “proactive” made this aspect of the SMS worldview virtually inevitable.

Finally, the often-desirable separation between civil aviation authorities and investigating authorities seems to have fostered an environment within which SMS processes are deliberately held separate from the work of investigation. This is explicable, but not necessarily appropriate. Investigators have a singular focus, and CAAs must bring other considerations to bear on the feasibility of their proposals. However, accident investigations findings and recommendations deserve to be brought under a “management” umbrella to ensure they are properly considered and implemented where practical. Such handling is not facilitated by the present vision of SMS.

Annex 19 lists the following as being components of an SSP, not an SMS:

- State safety policy and objectives,
- State safety risk management,
- State safety assurance, and
- State safety promotion.

Annex 19 also makes it clear that neither an SSP nor an SMS supporting it needs to be limited to the four elements alone. Appendix 2, “Framework for a Safety Management System” (SMS), explicitly states, "The framework comprises four components and twelve elements as the minimum requirements for SMS implementation.” [Emphasis added]

At the same time, the individual definitions of each show that many traditional aspects of aviation safety do not fit neatly under the new SMS umbrella. Critically, even the amplified discussion of the various components in Appendix 2 leaves open a key issue: where accident investigations actually fit into fully evolved SMSs. It also is silent on the question of how an SMS is supposed to take action as a part of “assurance”; “performance monitoring and measurement” is a far cry from analysis of data (a basic obligation of SSPs’ “state safety assurance”).

The fact that SSP and SMS concepts have become conflated over the past 15 years is evident in that, with the removal of the word “state,” the above SSP components are the key organizing principles for SMSs as well. In the quest to reconcile the two, the sensitivity to an SMS being “reactive” came to the fore. For example, Argentina’s Administración Nacional de Aviación Civil (ANAC) published SMS: Guía para la Evaluación de la Implementación (SMS: Guide for the Evaluation of its Implementation) that makes two observations illustrating the system’s incident-oriented perspective and the blurring of lines between SSP and SMS: “Mandatory reporting programs and incident investigation programs of
service providers are typical examples of programs for the reactive capture of safety data.” Internal safety [incident] investigations “include events of an operational nature that do not need to be investigated or reported to the state, for example, turbulence in flight, vehicle events on the ramp, etc.”

On the other hand, the SMS developed by Australia’s Civil Aviation Safety Authority (CASA) uses exactly the same components and guidelines, but explicitly provides for both incident and accident investigations as essential components of safety assurance: “Investigating incidents and accidents in a structured way is fundamental to an effective SMS. If you do not investigate incidents thoroughly, you cannot learn from them, and therefore will miss opportunities to identify risks to your operation.”

Despite SMS and SSPs being based on the same four “components,” Annex 19 calls for creation of specific SMS-related policies and processes—and a bureaucratic structure specific to their care and feeding—instead of simply identifying what should be done in constructing an SSP. This seems at once unnecessary and overly prescriptive. U.S. Army Gen. George S. Patton once said, “Never tell people how to do something. Tell them what to do, and they will surprise you with their ingenuity.”

What’s more, Attachment A contains a qualifying remark that seems to place SMS at a level at least co-equal with SSPs themselves: “The SSP framework introduced in this attachment, and the SMS framework specified in Appendix 2, must be viewed as complementary, yet distinct, frameworks.” In this context, the disclaimer sidesteps the fundamental difference between an appendix and an attachment in an ICAO annex: the former represents “material grouped separately for convenience but forming part of the SARPs adopted by the council,” while the latter comprises “material supplementary to the SARPs or included as a guide to their application.”

In short, in addition to the SMS guidance in Annex 19 failing to incorporate any reference whatsoever to investigations—either accident or incident—ICAO’s current approach to SMS seems overly prescriptive and tends to empower SMS as an institution instead of making it clearly subordinate to and supportive of the SSP it should be designed to support. Thus, an SMS is the expected outcome of the SARPs; SSPs essentially have been relegated to the role of enabling the operation of SMSs.

With respect to the role of accident investigations in the context of SMS, Paragraphs 2.10.5 through 2.10.7 in Document 9859 represent the sole ICAO guidance regarding the role of investigations in an SSP (i.e., SMS) environment. Their inclusion strongly suggests that the role of investigations was consciously addressed in the creation of Document 9859, but also that much of that thinking was not brought forward into Annex 19 SARPs.

**How SMSs work (and don’t work) with accident investigations**

The failure of SMSs to provide for accident investigations and their recommendations in their overall framework eliminates an invaluable source of knowledge for the SSP as a whole. If this was done in the interests of “maintaining investigators’ independence,” it has created a far more perilous situation: a purposeful blind spot regarding the most critical failures and actions proposed to correct them.

Perhaps part of the slippery slope that led to the embrace of SMSs was the push to be “proactive” rather than old-fashioned “reactive.” Coinciding as it did with the period of slowing rates of improvement in aviation accident rates, this was a reasonable goal to pursue. But to some extent, it seemed to look past the fact that most of the easy fixes and easy wins already had been achieved. The mere accumulation of large amounts of data does not automatically translate into actions or new insights.

In particular, the SMS concept seems to consistently downplay the necessity and value of investigations in general and accident investigations in particular. Many SMSs treat voluntarily submitted, purely preliminary reports not containing enough info upon which to act as if they are superior to reports on investigations of actual occurrences. That take bolsters the underlying philosophy of SMS as “proactive,” supports the notion that “safety culture” has preventive value, and costs a lot less.

Despite this institutional mindset, accident investigations and the recommendations resulting from them need to be properly baked into the fabric of current and future SMSs. “Proactive” outcomes need not be pursued exclusively through “proactive” sources of data; accident investigations should form the basis for follow-on inquiry, and their recommendations should be scrupulously tracked and managed. Moreover, any inappropriate risk acceptance or inadequate risk assessment discovered during an accident investigation needs to drive changes to the appropriate SMS functionalities. This is the essence of “safety assurance.”

Unfortunately, Attachment A to Annex 19 (which as noted above is not a part of the SARPs portion of Annex 19 proper) places accident and incident investigations under “state safety policy and objectives,” not “state safety assurance.” It is far from clear why this might be appropriate, since the latter explicitly encompasses “safety oversight, safety data collection, and most especially safety data-driven targeting of oversight areas.”

What’s more, Paragraph 5.3.92 of Document 9859 notes that safety managers should ensure that “lessons learned from investigations and case histories or experiences, both internally and from other organizations, are distributed widely.” However, this is characterized as a “safety promotion” function instead of a core preventive activity that should be aggressively pursued under the SMS as a function of safety assurance.

Finally, the 11th edition (2016) of Annex 13, *Aircraft Accident and Incident Investigation*, has been effectively scrubbed clean of any remnants of references to either SSPs or SMS. The previous edition’s Attachment F, “Framework for the State Safety Program” (SSP), was transferred in its entirety to Annex 19—which makes sense—but there no longer is anything
in Annex 13 to suggest that accident investigations are in any way a part or a function of SSPs themselves.

Annex 19 is essentially silent on the roles of investigations or recommendations in the context of proactive accident prevention. By the same token, Annex 13, Chapter 6, talks a lot about recommendations, despite the fact that Annex 19 indicates it brought all of the critical elements from Annex 13 into its SARPs for SMS. This leads one to wonder whether Annex 13 and Annex 19—representing the “reactive” and the “proactive”—actually are competing, or even in opposition with each other when it comes to a single approach to safety in civil aviation.

The answer, of course, is that there should be no competition at all. ICAO’s commitment to aviation safety is absolute. However, there is competition between the two respective philosophies of accident prevention they represent, which is unfortunate. SMS is no more the “right” strategy for reducing accidents than is any other strategy. It should be informed by any and every approach to prevention available, even if such approaches lie outside the purview of those implementing the SMS itself.

These examples strongly suggest that the very notion of accident investigation is in danger of becoming completely delinked from the practice of aviation safety by SMS following the ICAO model. The power and import of accident investigations and recommendations are being diffused through the various SMS components instead of leveraged for their maximum preventive value.

The investigator’s challenges in working within (and outside) SMSs
As this monograph has made clear, accident investigations do make a difference, but the SSPs and SMSs with which they need to interact and cooperate have become increasingly distanced from the accident investigation process and products. To address this trend, the air safety investigator community needs to do three things:

- Demonstrate the proven, ongoing value of investigations and the recommendations that flow from them,
- Find the best fit for both the investigation process and its resulting outputs in the context of the existing SMS, and
- Highlight every instance in which the structure impedes the effective pursuit of safety. In other words, show where the SMS itself needs fixing.

There are positive examples all over the world that can be pointed out as alternate means of thinking about “safety management” that do not rely on strict conformity to Annex 19. Some state implementations of SMS are far more flexible and inclusive than others.

For example, Transport Canada highlights the fact that “SMS is based on the idea that you can always find better ways to prevent hazards, so the system will always be changing.” The program follows a somewhat different organizational structure as well, rooted in the

Figure 1. AFSMS (AFI 91-202, the U.S. Air Force Mishap Prevention Program, June 24, 2015).
“four Ps of safety management”: philosophy, policy, procedures and practices. While the first “P” embodies the generally accepted principle of “safety culture” and the second maps reasonably well to ICAO’s “policy and objectives” component, the latter two are quite different. They are described in the Introduction to Safety Management Systems (TP 13739) as follows:

• Procedures—What management wants people to do to execute the policy: clear direction to all staff; means for planning, organizing, and controlling; and means for monitoring and assessing safety status and processes.

• Practices—What really happens on the job: following well-designed, effective procedures; avoiding the shortcuts that can detract from safety; and taking appropriate action when a safety concern is identified.

The U.S. Air Force Safety Management System (AFSMS) contains a significantly more detailed mapping of specific preventive activities than that of Annex 19 (see Figure 1). AFSMS unequivocally establishes all investigations as part of the “assurance” component. It also uses the useful term “improvement opportunities” for that subset of inputs subject to analysis and assessment within the assurance process. This places investigators’ recommendations under the same SMS component as the investigations themselves.

These examples show that it is possible—and even necessary—to think of SMSs holistically, not just as a fill-in-the-blanks exercise in conformity to SARPs. Each state needs to start with Annex 19 but needs not stop there.

The road ahead
As detailed above, the current state of affairs regarding accident investigations in the SMS environment can be summed up in a few propositions:

Proposition 1: The concept of SMSs is intolerant of investigations and their value because the reactive nature of investigations runs counter to the proactive nature asserted by SMS proponents.

Proposition 2: Fitting investigations into an SMS framework is difficult because SMS often treats the requirement to investigate as a policy, the investigative process as assurance, and the outputs as information simply requiring promotion. That portion of aviation safety dependent on effective risk management is mostly insulated from incorporating or acting upon lessons learned from accidents.

Proposition 3: Investigations do things that SMSs do not, and SSPs perform functions that cannot be subsumed under an overarching SMS. SMS should support SSPs, not the other way around.

Document 9756, Manual of Aircraft Accident and Incident Investigation, Part IV: Reporting, contains three telling passages that serve to prove why SMSs cannot do what investigations do:

• 1.1.1: “The findings and the causes of the final report should lead to safety recommendations so that appropriate preventive measures can be taken.” The focus of investigations is not on nonconformities or exceedances; it is on concrete failures and what can be done about them.

• 4.3: “A safety recommendation should describe the safety problem and provide justification for safety actions.” Accident investigations and the reports resulting from them are designed to explain. An SMS simply checks to see if “processes” have been followed and actions required under those processes have been taken or not, regardless of whether those actions were appropriate or even valid in the first place.

• 4.4: “During aircraft accident investigations, safety issues are often identified that did not contribute to the accident but that, nevertheless, are safety deficiencies. These safety deficiencies should be addressed in the final report.” You investigate, you find things that need attention, and you make recommendations. Under SMS, if the deficiency does not fit into the pigeonholes provided, such noncasual hazards may be lost.

In contrast to these explicit expectations associated with accident investigations, the overseers and advocates of narrowly proscribed SMSs seem to favor a popular but untested (and to some extent incomplete) philosophy. A rigid SMS composed only of Annex 19 minimum components promises much based on management theories and assumptions regarding a presumed relationship between accidents and “precursors.” However, it does not explain what should be expected of it upon implementation.

Nothing in the execution of SMS as described in Annex 19 can result in any insights whatsoever regarding why one sequence of events might have a worse outcome than another except “incident” investigation. In most cases, the focus of such inquiries is on determining what went wrong instead of what went right. Still, a forensic (“reactive”) look at such events often is warranted to determine why a more serious outcome did not occur.

Instead, lower-consequence incidents are treated as contributing to a “big data” understanding of hazards that somehow is to be used to facilitate proactive action. This begs a final question—What does an accumulated database of nonevents contribute to the prediction or prevention of more serious ones?

Like it or not, SMS tends to put two principles in opposition instead of leveraging their respective advantages. It pits the active against the passive, the hard work of investigation and analysis against the easy tasks of collecting and recording. Both have their place in the aviation safety professional’s toolkit, and neither should be disregarded or discounted.

As SMSs and “proactive approaches” continue to gain prominence, the need for effective investigations and well-founded recommendations that highlight their limitations has never been greater. Too-narrow approaches to prevention ultimately have to be considered in light of the old adage “when all you have is a hammer, everything looks like a nail.”
UAS Working Group Update

Over the past year, ISASI’s Unmanned Aircraft Systems (UAS) Working Group has provided major support to the International Civil Aviation Organization’s (ICAO) Accident Investigation Group, helping it move forward with a standalone guidance document for the investigation of UAS accidents and incidents. This effort was discussed at the last UAS Working Group meeting at the 2017 ISASI annual seminar, and members subsequently provided significant input to the initial and final drafts developed over the following six months.

The original plan, reports Tom Farrier, UAS Working Group chair, was for this guidance to become a new chapter in ICAO Document 9756, Part III. However in May 2018, attendees at the Accident Investigation Panel meeting (AIGP/4) in Montreal, Quebec, Canada, concluded that the sheer size of the UAS guidance (more than 120 pages) and its inclusion of context and reference material on the unmanned sector warranted publication as a separate ICAO document. This process is now under way at the ICAO Secretariat.

Creating standalone guidance on UAS issues that relate to existing annexes is precedent setting for ICAO. The Remotely Piloted Aircraft Systems (RPAS) Panel has been addressing similar needs across the entire spectrum of aviation, from pilot and aircraft (system) certification to differences in UAS adherence to “rules of the air.” The forthcoming AIGP document will follow the practice established by Document 10019, Manual on Remotely Pilot Aircraft Systems (RPAS). Its publication date is to be determined but will be announced through ISASI channels when known.

The UAS Working Group’s next project will be to develop guidelines for using UAS—both small and large—to support accident investigations. ISASI members have published several excellent articles and papers on this subject over the last several years. The new initiative will gather all this valuable information, along with more current thinking and applications, into a single-source document.

UAS Working Group members will be receiving e-mail notification of this project and available opportunities to contribute later this fall. The current plan is for development to proceed on a collaborative but distributed basis over six to eight months and then to discuss an initial draft at a face-to-face breakout session during the 2019 ISASI annual seminar in the Netherlands. If you’re an ISASI member and are interested in joining this effort, please contact the working group’s chair at farriert@earthlink.net.

Accident Investigation Training in Bahrain

On April 8–12, the Aircraft Accident Investigation Sector of the United Arab Emirates held a basic aircraft accident investigation training course for aviation professionals in Bahrain. The objective of the training was to provide the participants with the knowledge and skills to take part in an incident or accident investigation as competent team members.

The Bahrain civil aviation authority invited air accident investiga-
tigators Hans Meyer and Mohammed Abdul Bari to share their knowledge and experience and to provide the participants with the awareness and knowledge of the processes of an aircraft accident or incident investigation.

The participants came with a range of experiences, including director of aviation safety and security, head of standards licensing and development, manager of emergency response planning, airworthiness inspectors, air navigation audit specialists, military safety personnel, and qualified personnel from other aviation areas.

The course was based on International Civil Aviation Organization (ICAO) Annex 13 and ICAO Document 9756—Manual of Aircraft Accident and Incident Investigation—and covered a range of topics, including the responsibilities of the states; the objective of accident investigations; the definition of accidents, serious incidents, and incidents; the role and responsibilities of the investigator-in-charge, accredited representatives, observers, and technical advisors; the composition of investigation teams; states’ accident preparedness and the notification process; the investigator’s go-kit; accident site management; the hazards at the accident site; accident site safety; personal protection; collection of evidence; managing the news media, on-site and off-site investigation processes; witness interviews; handling and analysis of evidence; handling onboard recorders; wreckage reconstruction; crashworthiness and survivability; human and organizational factors; and findings, including causes and contributing factors. The week finished with report writing and the importance of safety recommendations.

The participants discussed recent and historic accident scenarios and conducted group exercises in which they developed investigation tasks flow charts, identified hazards at different accident sites, and recommended protective measures. The participants also identified investigation team specialties for nominated accidents and developed specific questions for initial witness interviews. Each team nominated an “investigator-in-charge” who then presented the team’s work to the class.

While there was a lot of information to cover in five days, the course was well received by participants, who are looking forward to increasing their knowledge with advanced courses.

Salah Mudara, the treasurer of the Middle East North Africa Society of Air Safety Investigators (MENASASI), visited the course on the last day to inform the participants about ISASI’s history, achievements, and objectives. All participants were invited to attend the ISASI seminar in Dubai on Oct. 29, 2018. This training course was accepted by the MENASASI board members as part of the Reachout program to enhance the investigation capabilities within the MENASASI region.

New ISASI Membership Committee Chair

On July 16, ISASI President Frank Del Gandio appointed ISASI Vice President Ron Schleede to be the chair of the Society’s Membership Committee. Schleede had been serving as acting chair for the past two years. Del Gandio expressed appreciation for his role as acting chair and noted that he was “instrumental” in a team effort to revise ISASI’s membership application.
ISASI Attends Fourth ICAO AIGP

ISASI, as an approved International Observer Organization, participated in the fourth International Civil Aviation Organization (ICAO) Accident Investigation Panel meeting (AIGP/4) in Montreal Quebec, Canada, on May 8–11. Ron Schleeide, ISASI vice president; Robert Macintosh, ISASI treasurer; and Thomas Farrier, ISASI Unmanned Aircraft Systems (UAS) Working Group chair, participated in the meeting. Twenty-one states and three experts from International Observer Organizations participated in the meeting.

The agenda included discussions on the following topics:

• Investigation procedures, techniques, and methodologies;
• Training guidelines;
• Testing for use of substances;
• Investigations involving remotely piloted aircraft systems (RPAS);
• Accident site environmental care;
• Accident investigation responsibilities—accident investigation authority versus state aviation authority;
• Safety recommendations of global concern;
• Recorded radar data;
• Guidance on final report content;
• Format and content for preliminary reports;
• Consultation period of draft final reports; and
• State of manufacturer of flight recorders.

All topics were of interest to ISASI members, and the ISASI delegation contributed to all discussions. Several amendments to ICAO standards and recommended practices and updates to guidance material have resulted from the work of the AIGP over the past four years. Of particular interest to ISASI at AIGP/4 were agenda items 4 and 7. Regarding item 4, Farrier had prepared a complete document regarding the investigation of RAPS over the past two years using the original material that he and his ISASI working group had prepared—UAS Investigation Handbook and Accident/Incident Investigation Guidelines, which was published in 2015. The updated materials completed by Farrier and the working group will be published as guidance material by ICAO. The document will supplement the Manual of Accident and Incident Investigation (Document 9756).

It was rewarding to see another ISASI working group product lead to the publication of ICAO guidance material—as was the case with the Cabin Safety, ATC, and Investigator Selection and Training ISASI Working Group products over the past several years.

Item 7, safety recommendations of a global concern, was equally rewarding and a huge success for ISASI. At AIG08, the ISASI delegation presented a working paper urging ICAO to establish a database of safety recommendations issued by states and the safety actions taken that other states could use. The ISASI working paper was supported by France and other states.

Over the past 10 years, additional efforts have taken place. And at AIGP/4, several standards and recommended practices were proposed to ICAO for adoption that will lead to significant amendments to Annex 13 and guidance materials regarding this subject. States will be required to forward to ICAO safety recommendations of a global concern, as well as the responses and safety actions taken by recipients of the recommendations. All of the materials will be available to other states for accident prevention purposes.

This is another example of ISASI’s value as an active International Observer Organization at ICAO.

ESASI 2018 Held in Latvia

The European Society of Air Safety Investigators (ESASI) held ESASI 2018 in Riga/Jurmala, Latvia, on May 22–23, with more than 120 delegates from Europe and neighboring regions attending, including those from the Middle East North Africa Society of Air Safety Investigators.

Ivars Gaveika, director of the Transport Accident and Incident Investigation Bureau (TAIIB) of Latvia, opened the seminar. Edgars Tavars, the parliamentary secretary of the Ministry of Transport of Latvia, delivered a keynote address on the importance of safety investigations in the aviation system.

For the first time, the International Civil Aviation Organization (ICAO) European and North Atlantic (EUR/NAT) office was part of the ESASI program. Arnaud Desjardins, deputy head of the Investigations Department of France’s accident investigation bureau, highlighted the upcoming amendments to Annex 13 and the accident and incident investigation capabilities of states in the ICAO EUR/NAT area of accreditation. The seminar included a variety of presentations on topics such as updates on regulations (ICAO, EU), case studies, investigation techniques, family assistance, emergency response plans, safety management systems, and human factors.

ESASI President Olivier Ferrante reported that this year the airline community was better represented than in previous years with participants from Aer Lingus, Air Italy, Austrian Airlines, Bluebird Cargo, and British Airways. The seminar was also marked by the formal or informal participation of neighboring societies such as the Middle East North Africa Society of Air Safety Investigators represented by Thomas Curran, AsiaSASI represented by Thomas Wang, PakistanSASI represented by Syed Naseem Ahmed, and the Regional Society of Air Safety Investigators represented by Sergey Zayko. Caj Frostell, ISASI’s international councilor, also attended the seminar.

During the seminar, S.V. Zayko, first deputy to the Interstate Aviation Committee chair, presented an award to Gaveika on behalf of the Interstate Aviation Committee. This appreciation echoed the thanks of the ESASI delegates for the great Latvian hospitality.

The European Society of Air Safety Investigators (ESASI) board during a meeting with ESASI members at the end of the first day of the seminar. Shown from the left are Steve Hull, secretary; Brian McDermid, Technical Committee; Robert Carter, European councilor; Olivier Ferrante, president; Thorkell Augustsson, committee member; and Matt Greaves, treasurer.
The Southeast Regional Chapter (SERC) recently held its 10th meeting since reactivating in 2009. This year’s gathering, reports SERC Secretary Alicia Storey, took place July 27–28 in Savannah, Ga., USA, and attendees experienced two days of activities that provided both information and entertainment.

Gulfstream Aerospace sponsored key events. The company provided a tour of its facilities on Friday during which participants were able to view the Gulfstream 500 and 600 on the production line. Gulfstream additionally provided all transportation (via motor coach) to and from the hotel and hosted dinner Friday evening at the famed National Museum of the Mighty Eighth Air Force. SERC thanks Gulfstream Aerospace and, as with other past sponsors, is truly appreciative of the contributions.

Saturday morning began with a presentation that Dr. Bjorn Hennig led on crew fatigue and then carried over with Capt. Shem Malmquist’s presentation on casual analysis using STAMP. After a short break, Joe Hopkins discussed decision-making, sharing his experiences with mission safety. Andy McMinn followed with a metallurgical look at a case study of the Beech K35.

After lunch, Glenn Grubb resumed the seminar with an enlightening presentation on daytime black holes, Robert ”Hoot” Gibson, a former astronaut, covered some common accident scenarios. Gerhard Coetzee discussed runway excursions at his business location in Almaty, Kazakhstan. The presentations ended with Trevor Ashline introducing the concept of integrating racing safety restraint systems into private aircraft.

This year has been productive for SERC. In 2019, SERC will be seeking new officers, and the request for nominations will be coming soon. Possible locations for next year’s meeting include the U.S. cities of Atlanta and Savannah, Ga.; Memphis, Tenn.; Charleston, S.C.; and New Orleans, La. •

SERC Holds 10th Annual Meeting

SERC 2018 participants review typical causes of air accidents.

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Charles "Chuck" Foster, 96, a long-time pilot and pioneer in American aviation safety, died on April 10, 2018, in Issaquah, Washington, USA. He joined ISASI in 1986 and was a Life Associate Member. Chuck was instrumental in creating the successful ISASI 1995 seminar held in Seattle, Washington.

As a youngster, he looked up to see a barnstormer fly over his hometown of Heavener, Oklahoma, USA. Chuck claimed this was the moment that forged his passion for aviation.

At Heavener High School, he played trombone, became an Eagle Scout, and was valedictorian of his class. A proud Sooner, Chuck graduated from the University of Oklahoma with a BS in mechanical engineering. Subsequently, he was assigned to the Air Force research and development program at Wright-Patterson Air Force Base in Dayton, Ohio, USA.

Chuck’s life-long goal, though, was to fly for the Air Force. The highlight of his flying career was his tour of Hokkaido, Japan, and Naha Air Base, Okinawa. He commanded the 16th Fighter-Interceptor Squadron on Naha, where he was the first to fly the all-weather single-seat supersonic F-102A Delta Dagger. As part of the 51st Fighter Interceptor Wing, Chuck’s unit was recognized by the Air Force for its deployment to Taiwan in the 1958–1959 crisis, specifically for deployment within four hours of the official notification. The unit demonstrated outstanding night flying in weather below minimums, landings as low as 200 feet, and 1/16th of a mile visibility.

His next two tours of duty were quite different. First he headed the ROTC program at the campus of San Francisco State University in San Francisco, California, USA, during the Vietnam War. Then Chuck was assigned to the Pentagon in Washington, D.C., USA. He retired from the Air Force in 1967, having been decorated with the Air Force Commendation Medal and Legion of Merit for his work in sonic boom research. Chuck served as a U.S. representative to the international meetings of the International Civil Aviation Organization on aircraft noise. He joined the U.S. Department of Transportation as director of noise abatement. His work included determining the impact of supersonic transport aircraft flying across the U.S.

Chuck continued his career in aviation with the U.S. Federal Aviation Administration (FAA). He was honored at the White House by President Jimmy Carter for his work developing aviation safety and certification standards, the FAA’s “Lead Region” concept, and for his work as the lead investigator of the tragic 1979 Chicago DC-10 crash. During the investigation, DC-10s were grounded worldwide.

Working as the FAA director of the Northwest Mountain Region allowed Chuck the opportunity to enjoy the area of the country he loved the most and continue his passion for aviation. The Northwest’s beauty and its hunting and fishing opportunities brought together his life-long joys. Chuck retired in 1986 from the FAA but continued in aircraft consulting work and became a proud member of the Seattle Hanger QB. Always a pilot, his last air adventure occurred on his 80th birthday when he piloted a glider.

A memorial service was held for Chuck on July 28 at the Seattle Museum of Flight.

WITH EVERYONE HE MET, CHUCK SHARED A STORY AND DELIGHTED THEM WITH HIS OPENNESS AND HIS GENUINE CONCERN FOR THEIR LIVES.