FORUM

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Air Safety Through Investigation

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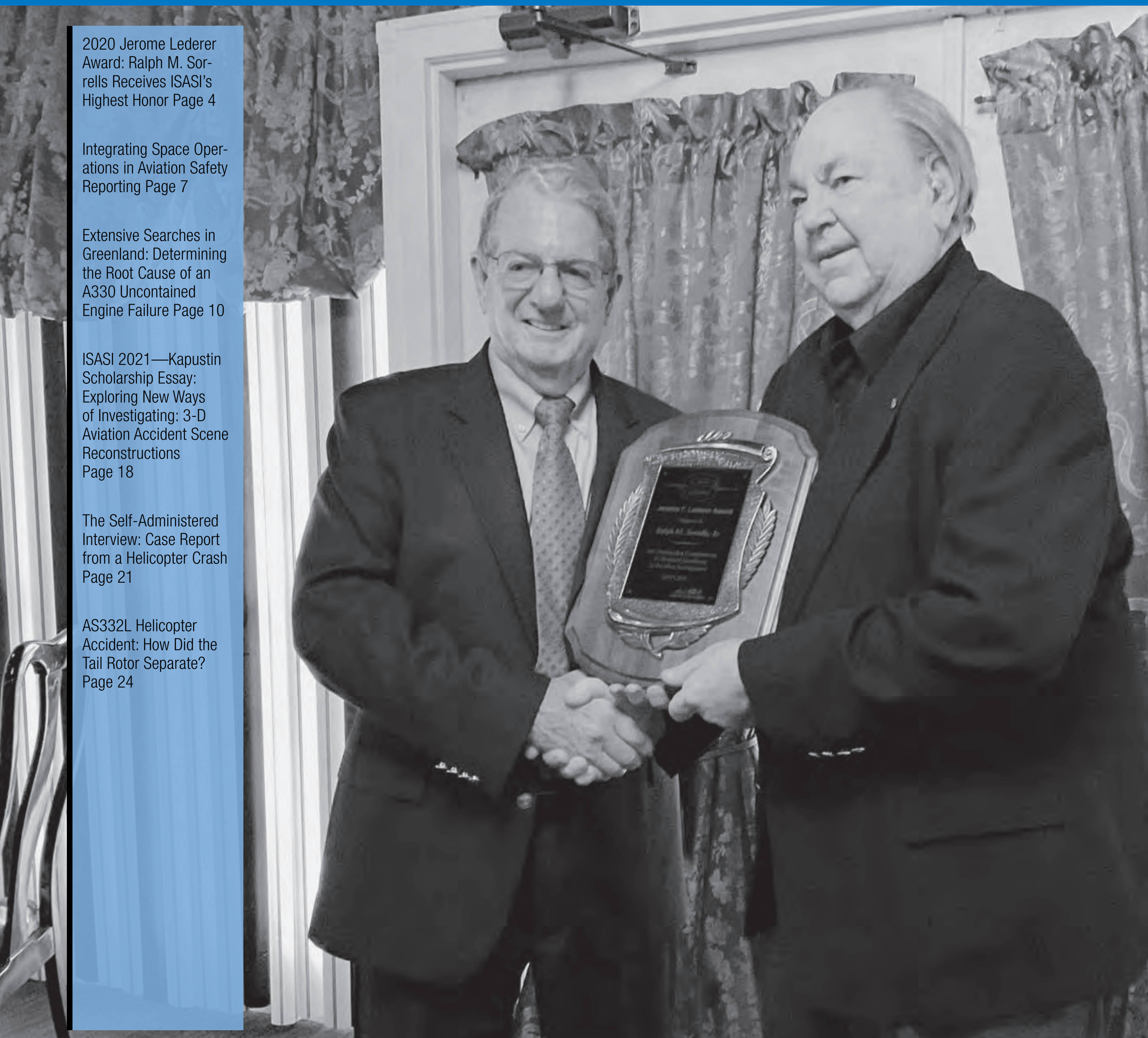
Journal of the International Society of Air Safety Investigators



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ISASI President Frank Del Gandio congratulates Ralph M. Sorrells, recipient of the 2020 Jerome Lederer Award, ISASI's highest recognition for air safety. The ceremony was postponed due to COVID restrictions that led to changes for the annual ISASI seminar.

FORUM ISASI
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AIR SAFETY INVESTIGATORS
INCORPORATED AUGUST 31, 1964

ISASI'S ORIGINS

ISASI has come a long way from its rather humble beginning during the spring of 1964 when a few U.S. Civil Aeronautics Board (now the U.S. National Transportation Safety Board) accident investigators decided to create a professional organization dedicated strictly to aviation safety—the Society of Air Safety Investigators (SASI). The Society's incorporation the following year and subsequent membership recruitment efforts led *The New York Times* to report that "air detectives" had formed a new organization. Charter members were recognized as anyone joining SASI before June 30, 1965. By that date, 139 individuals and two corporations, United Airlines and the Air Line Pilots Association, had signed on.

Annual dues for an individual member were $10 and for a corporate member $250. The Society at that time was international only in the sense that accident investigators in the Civil Aeronautics Board offices outside the U.S. began to join. In 1967, annual dues were reduced to $3 for individual and associate members, $100 for corporate members, and $25 for institutional members "until we develop some programs that would justify the expenditure of more funds."

In 1966, the Society established a bulletin, *PDQ*, to provide periodic information and news to SASI members. Two years later, SASI began publishing *SASI Forum* on a quarterly basis. This was originally a letter-size paper publication. The present day *ISASI Forum* was the work of Marty Martinez and now Gary DiNunno.

I find it interesting that Jerry Lederer during a speech to SASI members during January 1968, when he was with the Office of Manned Space Flight, suggested the Society might want to change its name to the Society of Aerospace Safety Inspectors as he observed that there would certainly be accidents during spaceflight. Lederer, for whom the Society named its highest award for promoting and enhancing air safety investigation, joined SASI in 1965 and served as the Society's second president from 1968 to 1970.

SASI's first annual forum for air safety investigation occurred in 1970 in Washington, D.C., at the Sheraton Park Hotel. The theme of the seminar was "Investigation is the Keystone of Progress." The seminar was opened by President Jerry Lederer. His opening statement at the first seminar was, "Well, I want to welcome you to the first international seminar on air accident investigation. It's an experiment which we hope will go far. You'll have an opportunity here to meet with people and discuss problem areas with people whom you will meet later when accidents occur in countries other than you own. In addition, of course, we will be able to exchange ideas on new techniques as well as the old proven techniques on aircraft accident investigation."

In 1976, the Code of Ethics for Society members was drafted and presented to the SASI Council and then underwent review and amplification for several years until a final version was accepted. Changes to the Society's Constitution in 1976 allowed formation of national and regional societies, and Australian and Canadian Societies were established in 1977. SASI officially became ISASI in 1978. Canada had actually started a chapter in 1973. The United States Society was formally established in 1984 and the Russian Society in 1996.

The Board of Fellows was organized in 1993, and Ludwig Benner was the first member elected to that status. From 1965 through 2001, there were seven individuals elected to honorary membership: Alan Boyd, Najeeb Halaby, Charles Murphy, Mike Monroney, Walter Tye, Joseph O'Connell, and James Oberstar.

In 1996, I was elected to the secretary position. I worked with Olaf Fritsch, Ira Rimson, Paul Mayes, Marty Speiser, Max Saint-Germain, Ron Chippendale, Jim McIntyre, Jim Stewart, Barbara Dunn, Capt. Robert Patterson, Marty Martinez, C.O. Miller, Dick Stone, John Rawson, Rudy Kapustin, Bill Hendricks, and George Oldfield. These are some of the folks during that period who worked hard and continued to lay the foundation for ISASI's future. ◆

Frank Del Gandio
ISASI President

Ralph M. Sorrells Receives ISASI's Highest Honor

By J. Gary DiNunno, Editor, ISASI Forum

(This article is compiled from Ralph Sorrell's award nomination and acceptance speech.—Editor)

Regarding the 2020 Lederer Award recipient, ISASI President Frank Del Gandio remarked, "Ralph M. Sorrells was selected to receive the 2020 Jerome F. Lederer Award—ISASI's highest honor for lifetime achievements to improve air safety. He opted to postpone receiving his recognition when ISASI 2020 was canceled and again when ISASI 2021 became virtual the following year. With ISASI 2022 now scheduled as a hybrid gathering—virtual and in person—he agreed to forgo the seminar ceremony. On March 29, 2022, I had the distinct pleasure of presenting the Jerome F. Lederer Award to Ralph in Addison, Texas. I was truly honored to bestow this prestigious award, and his acceptance speech to our small group was very moving. He is truly worthy of the award and very humble in his acceptance.

"I have worked with Ralph since 1983 when he became the director of product integrity [an accident investigator] at Mitsubishi, and it was always a pleasure to renew our acquaintance at the annual ISASI seminars, which he regularly attended."

Ralph M. Sorrells has been actively engaged in aviation for 59 years. He started his aviation career in January 1960 following his graduation from Texas Tech University where he received a bachelor of engineering degree. He continued his education and received a masters degree in aerospace engineering in 1973 from the University of Texas and maintained a 4.0 GPA while working full time.

Sorrells's first job was with Boeing Aircraft Company in Seattle, Washington, where he initially worked as a liaison engineer. He later moved to Dallas, Texas, and worked at Ling-Temco-Vought for 11 years as a stress analysis engineer. In July 1977, he was hired at Gates Lear Jet as a product support engineer (an accident investigator). Sorrells performed his first accident investigation in March 1978 in Brazil. He did four Learjet accidents and then accepted employment with Mitsubishi Aircraft International (MAI) in January 1981 and assumed the position of director of product integrity in 1983. When MAI air safety activities transferred to Mitsubishi Heavy Industries America, Inc. (MHIA) in 1990, he was subsequently appointed deputy general manager of aircraft product support. He was still employed with MHIA 39 years later.

During his career at Mitsubishi, Sorrells investigated more than 86 aircraft accidents. Prior to his employment with Mitsubishi, the MU-2B had a poor safety record. Going beyond probable cause, he proposed and implemented numerous safety-enhancing programs to improve the MU-2B safety record. Thanks to the safety initiatives he developed and proposed, the MU-2B now has the lowest fatal accident rate of any high-performance general aviation turboprop aircraft.

In the early 1990s, Sorrells's investigative research concluded that the lack of standardized flight training was the predominant cause of accidents for this category of aircraft. As a result of his findings, Sorrells launched a 10-year campaign to convince the U.S. Federal Aviation Administration (FAA) to require a type rating for this category of aircraft. Along the way, he participated in FAA-conducted special certification reviews, reintroduced the acclaimed Pilot Proficiency Program, and educated congressional leaders regarding the need for standardized training for general aviation pilots to significantly improve the safety of their operations.

Largely through Sorrells's continued efforts to address the safety of the MU-2B fleet and his interaction with the FAA as well as industry experts and aviation professionals, the FAA made standardized training mandatory for MU-2B turboprop airplanes. This standardized training program titled Special Federal Aviation Regulation (SFAR) 108 was issued in 2008, mandating annual flight training for MU-2B pilots in the United States. Since the inception of SFAR 108, now permanent regulation 14 CFR Part 91 Subpart N, the accident rate for the MU-2B is one of the lowest of all turbo-propeller-driven airplanes. Sorrells's relentless effort was instrumental in substantially improving safety in this area of aviation.

His work is continuing to this day with the introduction of a state-of-the-art angle of attack (AOA) system for MU-2B airplanes to give pilots continued awareness of stall margins even while maneuvering. The AOA system is now recognized as a safety-enhancing instrument in general aviation with support from both the FAA and the U.S. National Transportation Safety Board. His vision has led MHIA to become the safety leader among high-performance general aviation airplane manufacturers.

In recent years, Sorrells has been actively engaged in providing presentations on his past accident investigation experiences and advocating how MU-2B mandatory standardized training dramatically improves flight safety.

Sorrells is an aviation safety professional of the highest degree. His background, training, and experience, coupled with his expertise, have resulted in many changes to aircraft training and the aviation system. A flight instructor and commercial pilot with multiengine and instrument ratings, he joined ISASI in 1985 and has attended almost every seminar and is a true supporter of ISASI.

"There is no doubt that his 59 years have made a very positive effect on aviation safety. Ralph M. Sorrells is more than worthy of the Jerome F. Lederer Award," Del Gandio s commented.

In accepting the prestigious award, Sorrells said, "To me, receiving the Jerome F. Lederer Award for 2020 is greater than winning an Oscar at the Academy Awards, and I humbly thank the International Society of Air Safety Investigators for recognizing my accomplishments and Yoshiaki Asako, MHIA MU-2 product support engineering director, for nominating me. Having known Jerry Lederer personally makes receiving an award in his name even more special.

"I was lucky to have considerable help as, together, we improved an airplane with a rather mediocre accident record, the Mitsubishi MU-2, which is now recognized as the safest turboprop in its class. There are so many whom I need to thank for their commitment to improve flight safety. But if I tried to list everyone who has helped me receive this prestigious award, I would overrun my allotted time for this acceptance speech. Over the years, I have had wonderful assistance from Mitsubishi Heavy Industries, ISASI, MU-2 pilots, customers, vendors, and even a few lawyers who promoted aviation safety and understood the need for improvements and provided much-needed support.

"Also, I need to thank my mother for stimulating my interest in aviation. When I was five years old, she purchased a model airplane kit for me.

"You older attendees in the audience probably remember what a balsa model airplane kit looked like in the 1940s…the Exacto-knife cuts, the small rectangular sticks, the detailed plans, the Testors glue, and the many colors of dope. I still remember the enticing smell of the last two items. Now, I suppose they would call that 'huffing,' but in those days, we could go down to the model shop and buy whatever we needed. Perhaps sniffing the glue and dope conditioned my young mind into thinking that I liked airplanes. So thanks, mom.

"I suppose all air safety investigators indirectly aspire to work themselves out of a job. After recommending and managing MU-2 safety programs for 39 years, I actually accomplished that goal. The MU-2 accident rate, which was too high in the 1980s, was reduced to almost zero by 2008, coinciding with the release of Special Federal Safety Recommendation 108, which later became regulation 14 CFR Part 91 Subpart N. Overall, I know that many lives have been saved since the MU-2 now has the lowest fatal accident rate of all high-performance general aviation turboprop aircraft.

"As far as my background is concerned, I have a BS and MS in engineering from Texas Tech and Texas University, respectively. I spent two years with Boeing, 11 years with Ling-Temco-Vought, three years with Gates Learjet, and ended up at Mitsubishi Aircraft International in January 1981 for the next 39 years. I hold a commercial, single, and multiengine flight instructor rating, and I received the University of Southern California [USC] Safety Certificate in 2001 after completing the accident investigation curriculum. And now, the Jerome F. Lederer Award.

"During my employment with MAI in 1981—which later became Mitsubishi Heavy Industries America, Inc. in 1989—I investigated more than 86 accidents, many of which involved fatalities. I was responsible for investigating MU-2, Diamond 1, and YS-11 accidents worldwide. In addition to the U.S., I investigated accidents in Canada, Brazil, France, Belgium, Germany, Switzerland, Australia, the Netherlands, Sweden, Austria, Italy, and Great Britain. Often these investigations required return trips for follow-up examinations.

"As a result of my investigations, it was obvious to me early on that training or the lack thereof was a prime factor in MU-2 accidents. So in 1989, I petitioned the FAA to initiate a type rating for the airplane—not because the airplane was difficult to fly but because in 1986 MAI ceased MU-2 production resulting in devaluation of the plane. It could be purchased for about the price of a Beechcraft Bonanza. Since the MU-2 was known to be very economical to operate and have an exceptional mission record, many were being purchased cheaply and being used as freighters or hauling checks for the Federal Reserve in all kinds of weather by low-time and/or inexperienced pilots. Inadequate training and maintenance became a major issue. No special training was required for a pilot to fly any multiengine complex turboprop, such as the MU-2, which had been certified to a maximum gross weight of 12,500 pounds and have a maximum of 11 seats. All a pilot needed to fly it was a multiengine rating. Accidents were bound to happen. It took more than 10 years of frequent prodding for the FAA to issue SFAR 108, which mandated annual MU-2 pilot training to a standard curriculum.

"As you might imagine, litigation resulting from accidents was occurring in the 1980s and early 1990s. A business associate and I went to Japan, met with a former president of MAI, and proposed reviving the successful Pilot Proficiency Program [PROP], seminars that were free biennial programs designed to establish a safety culture for MU-2 pilots. He understood the popular phrase 'Pay me now or pay me later'; i.e., provide free PROP seminars to reduce accidents or face additional litigation. While PROP was quite effective in reducing accidents along with certain airplane modifications, it was the mandated SFAR 108 training requirement that changed the MU-2 safety record to one of excellence.

"Following the ISASI principle of looking beyond the probable cause of accidents, I initiated and promoted certain modifications to enhance flight safety:

- Standardized all autopilot switch locations, which varied in many MU-2s and could cause confusion for pilots who flew different models.
- Reduced maximum nose-down trim from -20 degrees to 0 degrees to prevent excessive yoke force in the event of a runaway trim.
- Standardized emergency procedures for the autopilot and electric trim for all models.
- Added an automatic engine ignition system modification to prevent engine flameout if heavy rain or ice is ingested.
- Added a trim-in-motion modification to provide aural notification if an uncommanded "UP trim" is running.
- Added a modification to disconnect the autopilot if unintentional low airspeed occurs, which could happen when encountering in-flight icing conditions.
- Added a voice alert to activate for multiple unsafe conditions, some of which include unsafe landing gear, low cabin pressure, improper takeoff flap and/or condition lever configuration, and an alert of in-flight icing.
- Found U.S. vendors to manufacture more damage-tolerant stretched acrylic cabin and cockpit side windows to prevent blowouts and in-flight decompression.

"Most recently, I proposed the introduction of an inexpensive state-of-the-art AOA system for MU-2 airplanes designed to give pilots continuous awareness of stall margins even while maneuvering. It is effective for all flap settings and incorporates visual landing approach guidance and has a voice alert of an impending stall.

"In addition to my MHIA duties, I provided presentations on past accident investigation techniques and experiences to USC students, the FAA, the International Meteorology Society, the European Union Aviation Safety Agency, and other government-sponsored programs.

"In conclusion, although retired, I will honor Jerry Lederer by continuing to promote aviation safety at every opportunity. Thank you." ◆

PAST LEDERER AWARD WINNERS

1977—Samuel M. Phillips
1978—Allen R. McMahan
1979—Gerard M. Bruggink
1980—John Gilbert Boulding
1981—Dr. S. Harry Robertson
1982—H. Prater Hogue
1983—C.O. Miller
1984—George B. Parker
1985—Dr. John Kenyon Mason
1986—Geoffrey C. Wilkinson
1987—Dr. Carol A. Roberts
1988—H. Vincent LaChapelle
1989—Aage A. Roed
1990—Olof Fritsch
1991—Eddie J. Trimble
1992—Paul R. Powers
1993—Capt. Victor Hewes
1994—UK Aircraft Accidents Investigation Branch
1995—Dr. John K. Lauber
1996—Burt Chesterfield
1997—Gus Economy
1998—A. Frank Taylor
1999—Capt. James A. McIntyre
2000—Nora C. Marshal
2001—John W. Purvis and the Transportation Safety Board of Canada
2002—Ronald L. Schleede
2003—Caj Frostell
2004—Ron Chippindale
2005—John D. Rawson
2006—Richard H. Wood
2007—Capt. Thomas McCarthy
2008—C. Donald Bateman
2009—Capt. Richard B. Stone and the Australian Transport Safety Bureau
2010—Michael Poole
2011—Paul-Louis Arslanian
2012—Curt L. Lewis
2013—Frank Del Gandio and Myron Papadakis
2014—David King
2015—Ladislav (Ladi) Mika
2016—Eugene (Toby) Carroll
2017—Chan, Wing Keong
2018—Capt. Mohammed Aziz
2019—Capt. Akrivos Tsolakis
2020—Ralph Sorrells
2021—Keith Hagy

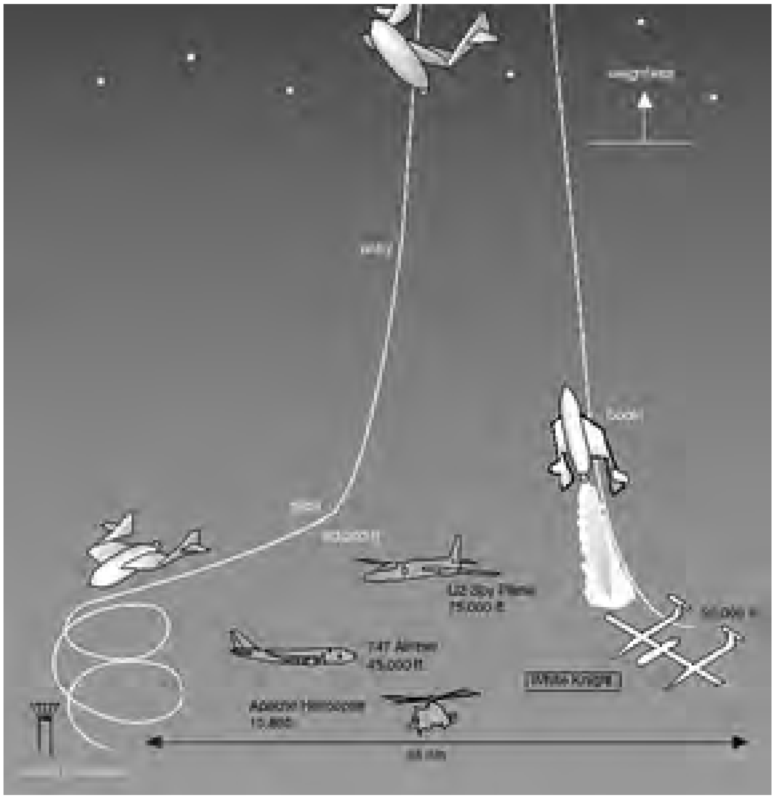

Figure 1. Space Ship One trajectory
Source: Scaled Composites

Integrating Space Operations in Aviation Safety Reporting

By Dr. Ruth Stilwell, Norwich University, College of Graduate and Continuing Studies, rstilwel@norwich.edu, and Dr. Diane Howard, University of Texas-Austin, Strauss Center for International and Security Law, diane.howard@law.utexas.edu

Space launch and reentry operations have a direct effect on airspace, and safety events in space operations can have safety consequences for aviation operations. For example, the *Columbia* shuttle disaster is often cited as posing a significant debris collision risk for civil aviation. While fatal accidents in U.S. space operations are investigated by the National Transportation Safety Board (NTSB), policy developments in each industry—aviation and space—have remained independent.

The Virgin Galactic accident in 2014 resulted in a recommendation to increase the development of the commercial space safety database. While this will eventually mirror the aviation safety databases, without integration the opportunity for comprehensive understanding of safety issues across domains is lost. Increasing pressure on airspace managers to reduce the amount of airspace protected for space launch will expand the overlapping interests of aviation and space operators.

At the same time, policy changes to increase the requirements on space operators to deorbit space objects will lead to increased reentry activity directly impacting aviation.

Ruth Stilwell

Diane Howard

(This article was adapted with permission from the authors' technical paper presented during ISASI 2021, a virtual seminar hosted from Vancouver, B.C., Canada, from Aug. 31 to Sept. 2, 2021. The theme for the seminar was "Staying Safe, Moving Forward." The full technical paper, Integrating Space Operations in Aviation Safety Reporting, *is available on the Society's website, www.isasi.org, in the Library section under the Publications and Governance/Technical Papers tabs.—Editor)*

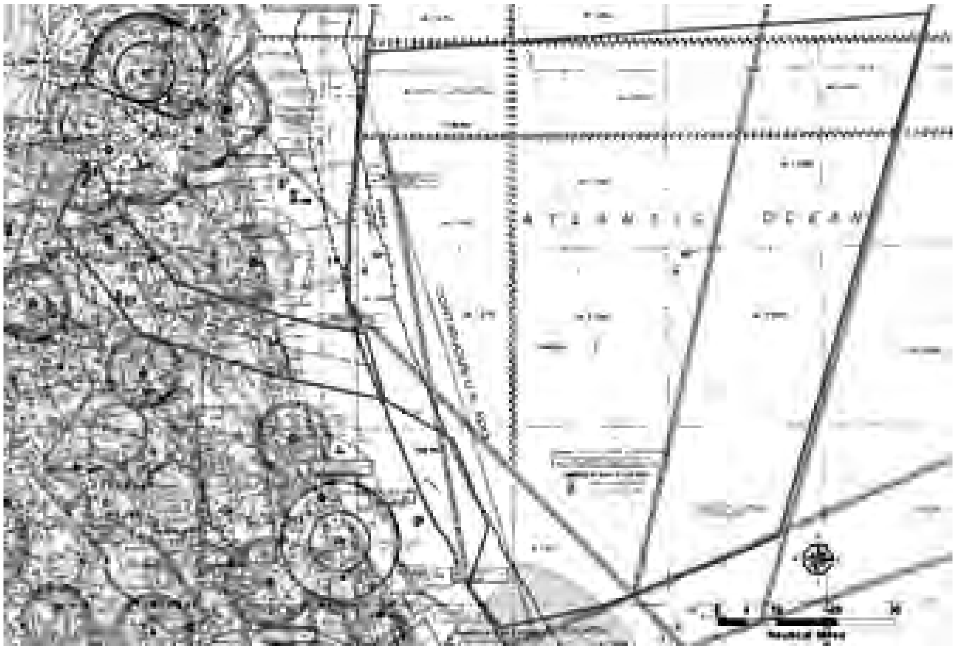

Figure 2. Cecil spaceport operating range. Source: Cecilspaceport.com

As the commercial space sector grows, so, too, does the interaction between aviation and space. For safety reporting, continuing to segregate safety data could create a gap in understanding that may be critical in preventing a future collision in civil airspace. This paper examines the evolving interactions between aviation space operations in civil airspace and the need for integrated safety reporting.

The Federal Aviation Administration (FAA) licensed the United States' first "spaceline" on June 25, 2021. The NTSB has had express jurisdiction to investigate commercial space launch accidents for more than 20 years. However, this overlap between aviation and space operations has not extended to safety reporting. As we have seen with the recent integration of unmanned aircraft systems (UAS) into aviation safety reporting systems, this is a critical step in the development of comprehensive safety management systems, but one that is often delayed.

The Blurred Line Between Aviation and Space

Scholars and practitioners have debated the line between aviation and space since the beginning of the Space Age. Throughout discussions, debates, proposals, and quests to find that defining line, the community is no closer to consensus than the day it began. Some have argued for a physical line, and others have argued for a functional one, but neither has found the clear distinction. As we have progressed from Sputnik to space tourism, the lines between aviation and space have become more intertwined, not less.

The increasing pace of space launch and reentry has an increasing impact on shared airspace. The development of launch vehicles from aircraft has coupled air and space operators, and the space plane bridges both domains.

While there is a clear functional overlap, the differences in air law and space law frameworks, both internationally and within the U.S., provide clear illustration of some of the effects resulting from the segregation of aviation and space activities from a policy perspective.

There are a number of points of divergence. For instance, air law is founded upon a state's sovereignty over its airspace, while a lack of sovereignty in outer space is a fundamental principle enshrined in the Outer Space Treaty.

However, several chief differences help demonstrate the effects of stovepiping. One is that space law allows no private right of recovery while aviation law has an entire body of private international air law governing such claims. Another is how we categorize people traveling on aircraft for hire as opposed to those noncrewmembers on a space flight. These can be government astronauts or spaceflight participants. Spaceflight participants in the U.S. are required to sign an informed consent, after a very detailed procedure ensuring their understanding of risks and indemnifying the U.S. government should anything go wrong—and in some states even indemnifying launch operators. Air passengers might have some limits to liability as per the Montreal Convention, but they are not precluded from bringing a claim per se. Yet another is that collisions involving spacecraft in airspace can mean absolute liability for the country that authorized its launch or agreed to launch it from its spaceport or territory, even if the accident could be deemed the fault of an aircraft operator. And the aircraft carrier's liability, absent gross negligence or intention, could be very limited by contract.

The social and political pressures involved in the metapolicy choices at the international level during the negotiations of the Chicago Convention in 1944 and the Outer Space Treaty in the 1960s are beyond the scope of this paper. However, within these two frameworks, a myriad of smaller operational policy choices is available to assist in managing the problems that can arise when these two transportation modes literally share the same operating domain.

Airspace Integration

Historically, space activity occurs in segregated airspace, with a hazard area created to ensure that nonparticipating aircraft are excluded from the protected airspace. The airspace management model has been static from the beginning of the Space Age and does not consider the innovation in launch models and pace of launch activity.

This model places a significant economic burden on the aviation community, disrupting hundreds of flights and delaying thousands of passengers for each launch. As a result, new models for airspace management that seek to reduce the size and duration of airspace management are emerging. The view that space actors, particularly commercial space operators, are airspace users to be integrated rather than an airspace hazard to be mitigated brings aviation and space even closer.

Launches are no longer an occasional event. They occur weekly and are getting more frequent. The current plans for recreational launches with human participants in 2022 will capture the public imagination, but it is the consistent cadence of launch to populate and refresh megaconstellations that will generate the greater impact on shared airspace. Shared airspace creates shared risk, and our most effective tool for mitigating risk is information.

Safety Reporting

As the operations begin to interact with one another, the ability to report and share information on potential safety events becomes critical. The benefit of an effective safety reporting system is accident prevention. This is common across all aviation safety reporting regimes, Skybrary consolidates the concept with this clear objective:

"Safety occurrence reporting aims to improve safety of aircraft operations by timely detection of operational hazards and system deficiencies. It plays an essential role in accident prevention, enabling the identification of appropriate remedial actions by prompt analysis of safety data and by the exchange of safety information."

The European Union Aviation Safety Agency puts it this way: "Experience has shown that accidents are often preceded by safety-related incidents and deficiencies thereby revealing the existence of safety hazards. Therefore, safety data is an important resource for the detection of potential safety hazards. In addition, whilst the ability to learn from an accident is crucial, purely reactive systems have been found to be of limited use in continuing to bring forward improvements. Reactive systems should be complemented by proactive systems, which use other types of safety data, to make effective improvements in aviation safety."

The aviation industry has recognized the value of proactive safety information but has yet to realize the value of proactive steps in creating the organizational frameworks necessary to collect that data from new entrants and those with emerging technologies. For example, the provisions for accident reporting for aircraft more than 55 pounds applied to drone operators, but the NASA Aviation Safety Reporting System did not add a report category for UAS until this year and does not have a category for commercial space operations. The certification of a spaceline to carry commercial spaceflight participants takes us one step closer to an integrated policy construct. Safety reporting systems provide an important link in that integration.

Sharing safety information is precisely one of the granular policy choices available that can constructively help manage the differences in legal systems governing these two modes of transport. Appropriate outreach to ensure that safety reporters and officers in both aviation and the space sector are speaking the same language is necessary. Currently, the space community is working on developing a standard for the classification of safety-related events. ASTM International Work Item No. 65152, Guide for Classifying Safety-Related Events, recently went to ballot to provide guidance on how to classify events and to define terms like severity and impact deemed necessary for effective classification. Sharing this standard with aviation safety personnel, and reciprocal communication from the aviation safety community, can potentially facilitate more comprehensive and usable reporting systems.

Conclusion

U.S. space launch operations, including reentry are licensed by the FAA. Commercial space operator accidents are investigated by the NTSB. Space launch operations occur in shared airspace, albeit temporarily segregated for the purpose of the launch. The overlap between aviation and space safety is recognized but falls short of integration. The integration of safety reporting mechanisms can provide benefits for both domains. The value of safety reporting is well established and a critical tool for accident prevention. However, it is too often an afterthought when integrating new entrants and new technologies. The opportunity to integrate commercial space operations into established safety reporting mechanisms should not be overlooked. ◆

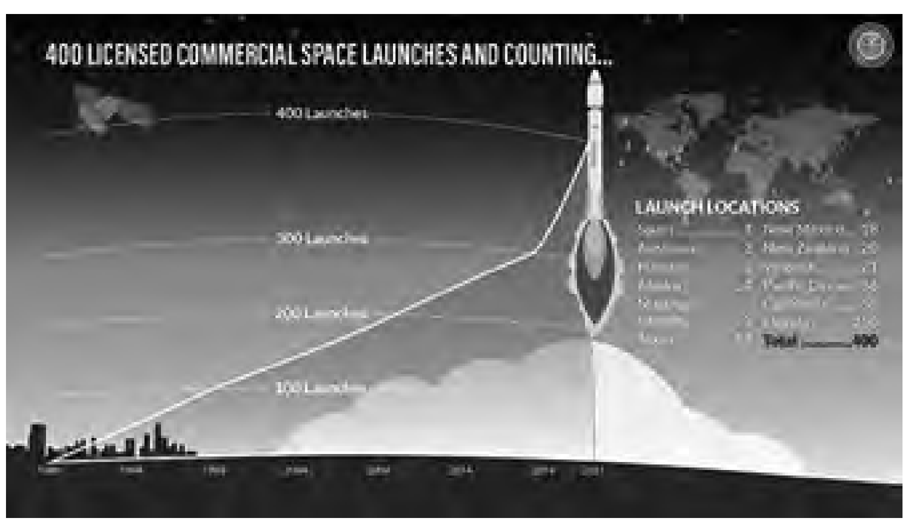

Figure 3. FAA-licensed commercial space launches.
Source: FAA

EXTENSIVE SEARCHES IN GREENLAND

INVESTIGATING AN A380 UNCONTAINED ENGINE FAILURE

By Stéphane Otin and Angélique Lefèvre, Air Safety Investigators, BEA (Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile), Le Bourget, France

(This article was adapted with permission from the authors' technical paper presented during ISASI 2021, a virtual seminar hosted from Vancouver, B.C., Canada, from Aug. 31 to Sept. 2, 2021. The theme for the seminar was "Staying Safe, Moving Forward." The full technical paper, Extensive Searches in Greenland Leading to Determination of Root Cause of an A380 Uncontained Engine Failure*, is available on the Society's website, www.isasi.org, in the Library section under the Publications and Governance/ Technical Papers tabs.—Editor)*

Stéphane Otin

Angélique Lefèvre

This paper summarizes a complex investigation that started with extensive searches over Greenland and then zoomed into the root cause using tools ranging from airborne radars to high magnification electronic microscopes. It made it possible to learn key safety lessons regarding engine materials. These should provide the community with a better vision for future aircraft and engine designs.

The Accident Investigation Board of Denmark (AIB DK) (representing Greenland and Denmark) delegated the safety investigation to the BEA in accordance with the provisions of Regulation (EU) No. 996/2010 and largely contributed to the search efforts in terms of both financial support and providing expertise.

A380 Diversion After Uncontained Engine Failure

On Saturday, Sept. 30, 2017, the Airbus A380-861 registered F-HPJE powered by Engine Alliance GP7270 engines, operated by Air France, was carrying out scheduled Flight AF066 from Paris, France, to Los Angeles, California. Approximately 4 hours after takeoff, while the crewmembers were changing the enroute flight level to FL380, they heard an explosion and observed asymmetric thrust from the right side of the airplane, immediately followed by severe vibrations. The "ENG 4 STALL" and then the "ENG 4 FAIL" messages nearly simultaneously appeared on the electronic centralized aircraft monitor. Pictures taken by passengers alerted the crew that it was facing an uncontained engine No. 4 failure.

The engine performed an automatic shutdown, and the crew confirmed the sequence by depressing the engine No. 4 master and engine No. 4 fire pushbuttons a few seconds later. The crew started the incident processing method FOR-DEC (Facts, Options, Risks & Benefits, Decide, Execution, Check) taught by Air France and initiated decent initially to FL346. Observing that it was not possible to hold this flight level and maintain airspeed due to the additional drag caused by the uncontained engine No. 4 failure, the crew continued descending level by level up to FL270 where the aircraft stabilized.

They diverted to Goose Bay Airport in Canada where they landed around 2 hours later without any further incidents.

A visual examination of engine No. 4 found that the fan, first rotating assembly at the front of the engine, along with the air inlet and fan case, had separated in flight causing slight damage to the surrounding structure of the aircraft.

Initial Failure Scenario and Immediate Safety Measures

Two days after the event, the data contained in the flight data recorder (FDR) was used to determine the path and the precise position of the aircraft when the failure of engine No. 4 occurred in order to launch ballistic computation to define a search zone and locate the fragments that had separated from it. In addition, examination of the damage on the engine and simulations of the engine failure carried out by Engine Alliance made it possible to determine that the fan hub had most likely separated into at least three fragments, and the size, weight, and direction of ejection of the fragments were estimated.

Even though pieces of debris were recovered on the ice sheet of southwestern Greenland days after the event, the key components were still missing. During the period when the conditions were not met to continue visual searches, and an extensive search campaign was being organized, the investigation team brainstormed on potential failure scenarios and associated immediate safety measures. The objective was to guarantee the airworthiness of the other engines in operation, preventing any further uncontained engine failure in this timeframe.

The failed engine had not been under specific monitoring, given its low number of cycles, operating hours, and maintenance history. The initial factual information gathered by the investigation did not point to one failure scenario.

Several service bulletins (SB) were published by the engine manufacturer after the accident requiring in-service inspections to be carried out. These inspections focused on the detection of potential damage in the fan hub regions that the manufacturer had identified as critical in terms of stress levels. The manufacturer's SBs were adopted as airworthiness directives issued by the U.S. Federal Aviation Administration (FAA) and European Union Aviation Safety Agency (EASA). These inspections were decided on without knowing the failure mechanism of engine No. 4, as the fan hub fragment had not yet been recovered. It was assumed that the origin of the crack was on the surface and on the front face of the fan hub. In the scope of the continuing airworthiness of A380 airplanes equipped with GP7270s and given the information and tools available at this point, the fan hubs were to be inspected to check that there were no cracks.

The visual inspections required by these first SBs published after the accident detected several cases of surface damage (scratches) on the front faces of fan hubs. In particular, damage 0.30 millimeters (0.012 inches) deep was found in a scallop (zone subject to some of the highest stresses in service), most certainly due to an object striking the front face of the hub. The use of inappropriate tools during blade removal maintenance actions could cause similar damage. No crack was detected during the inspections.

The failure simulations combined with the in-service inspection results gave rise to a scenario in which a maintenance operation to remove the fan blade lock ring could be at the origin of the damage observed on the front face of the fan hub, leading to the hub failure. In particular, the ring removal operation was described as difficult by the operators because of its stiffness, and the marks found during the hub in-service inspections were attributed to the use of inappropriate tools. This scenario was at that time considered the most likely failure scenario.

Consequently, the engine manufacturer designed a new blade lock ring. The new ring is more elastic, which facilitates the maintenance operations. Its deployment in the fleet started on Nov. 25, 2019.

Searches in Greenland

Air safety investigators determined quite early on that the recovery of the missing parts and, in particular, the fragments of the fan hub was essential to establish the circumstances and factors explaining this accident.

With the unstable weather conditions in Greenland, it soon became clear that a complementary search to the usual visual identification from a helicopter would be necessary. Searches in Greenland were made in several phases, which eventually led to the recovery of the missing fan hub parts.

Phase I

Search Phase I consisted of initially determining, straight after the occurrence, a "rough zone" based on data from the FDR where debris was likely to be found and to recover the pieces.

This zone proved to be a deserted terrain covered with ice, situated approximately 100 kilometers northwest of Narsarsuaq in the southwestern part of Greenland. During this 10-day phase, three helicopter flights were carried out and around 30 pieces of debris were recovered: fan blade fragments, the fan containment case, front cone fragments, the air inlet, and parts of the nacelle. No fan hub fragment was found at this time. Snow covered the parts still present in the zone, preventing further visual detections.

Phase II

Search Phase II consisted of assessing detection means to locate the hub fragments on the Greenland ice sheet as well

Figure 1. Extraction of fan hub fragment. Source: Austin Lines

as preparing and carrying out the search operations, which took place in April and May 2018. The detection means had to be compatible with the harsh environmental conditions in the zone where the debris had fallen and with all the associated operational constraints. For these reasons, spring 2018 was the closest period after the accident that could be considered for search-and-recovery operations. Two consecutive operations were set up:

- An aerial campaign, consisting of the use of synthetic aperture radars operated from an airplane, to try to detect and locate the missing parts under the layer of snow.
- A ground campaign, consisting of the recovery of the parts previously located during the aerial campaign, or in a systematic search with the help of ground-penetrating radar (GPR) if the aerial phase was unsuccessful.

Despite the efforts made in the operations previously described, the fan hub fragments were not detected at the end of June 2018.

SETHI, the technology of ONERA, a French aerospace lab, is experimental and its deployment over the ice sheet to detect parts buried under the snow was new. Due to both the higher-than-expected background scatter noise and the less-than-expected radar penetration, no target with a sufficient confidence level was detected in the relatively short time before the ground campaign carried out by GEUS started. ONERA finally indicated six moderate-confidence targets to GEUS for its ground campaign.

The GEUS ground campaign first focused on the targets detected in ONERA's aerial campaign. Once the six targets that had been provided had been explored without any debris being found, the ground campaign extended to a systematic search campaign. The GPR towed on the ice behind a snowmobile proved to be a suboptimal sensor for a wide-area search. In all, 430 kilometers of radar measurements were analyzed without being able to certify that if the part had been located under these swaths it would have been identified.

Despite the search zones being given priorities following the more accurate ballistic calculations carried out by Airbus and the U.S. National Transportation Safety Board, no debris was found before this second search campaign came to an end.

The assurance of the ONERA experts that it was possible to improve the processing of the radar data to identify high-confidence targets led the BEA to envisage continuing the work. The ONERA team continued processing the radar data acquired during the aerial campaign after the team's return to France. New specific algorithms led to promising results. In conjunction with this work, the investigation team thought that it was necessary to test new

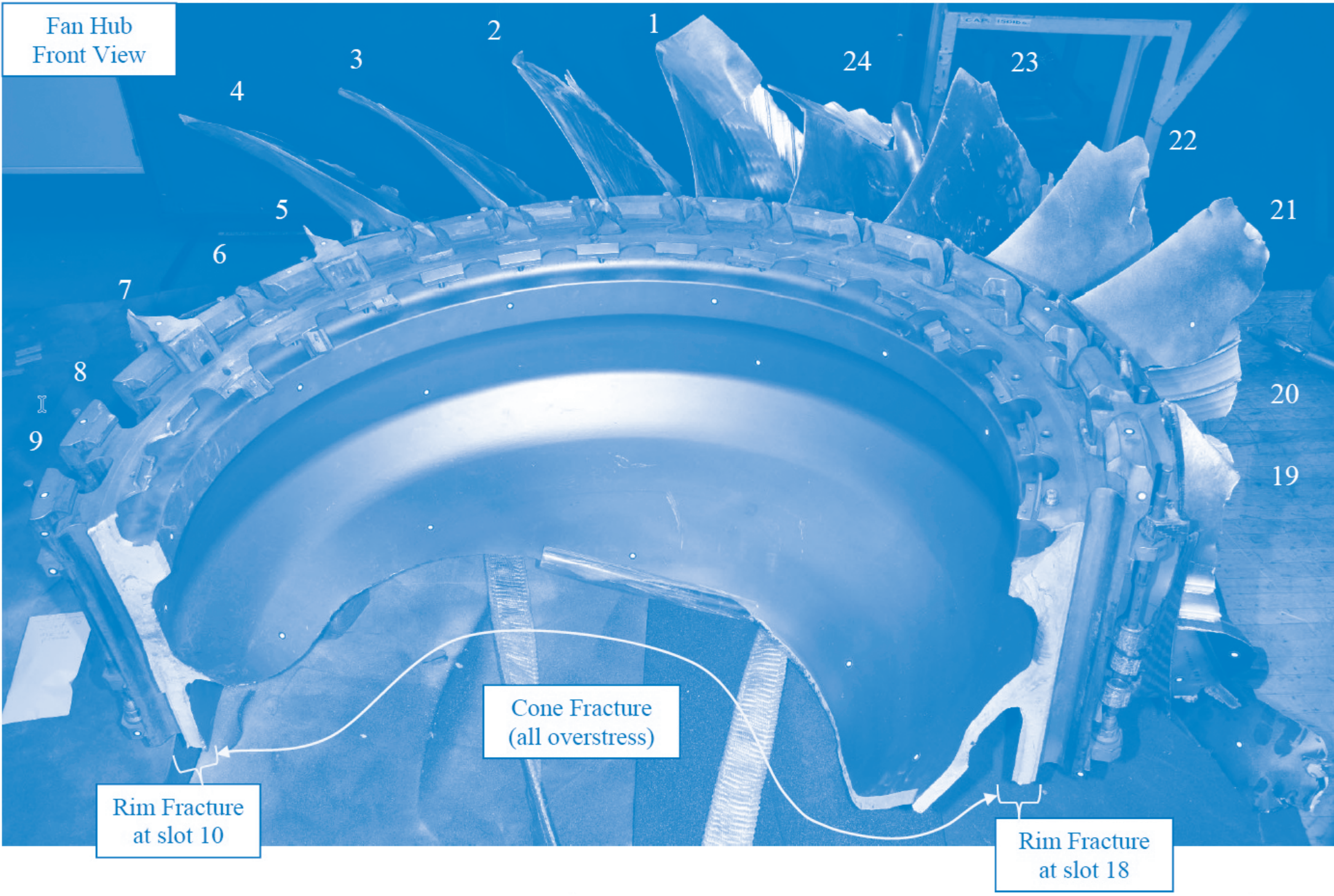

Figure 2. Fan hub fragment found in Greenland during Phase III. The slot numbers are given in white. The fracture surface extends from the bottom of slot No. 10 to slot No. 18, passing through the conical part of the hub (white line).

ground sensors with a wider swath and a more reliable signal return before initiating a new search phase in 2019.

Phase III

The engine manufacturer carried out engine failure simulations of a fan hub "bore to rim" fracture. The results were used to update the ballistic computations and refine the search zone. At the end of 2018, the Hydrogeophysics Group of Aarhus University in Denmark offered help to the investigation when it modified its electromagnetic detection system in order to detect a titanium part at a distance of 5 to 6 meters under snow. In parallel, ONERA completed its postprocessing of the radar data acquired during Phase II. ONERA sent the coordinates of one high-probability target and of two less obvious targets to the investigation team.

The decision to carry out a new expedition was made at the end of February 2019 for a departure in May 2019. The expedition kickoff was delayed due to weather, which shortened the mission duration. At the very end of the campaign, at the most promising spot indicated by ONERA, an unambiguous signal was recorded. Its position was close to the spot where the GPR had already made a detection, indicative of buried metal.

The detection was situated one meter north of a 4-meter-wide crevasse that had a 6-meter-thick bridge. The presence of the crevasse meant that it was not possible for the team to dig and retrieve the fragments at that time. An excavation campaign was organized in June 2019, which was able to carefully extract a fan hub fragment (see Figure 1) and transport it to an examination lab.

Examining the Fan Hub Fragment Found During Phase III

The fan hub fragment found in Greenland was sent to P&W in July 2019 to carry out an examination, supervised by the BEA. The fragment found is shown in Figure 2. Fan blade fragments were still attached to the hub. Two fracture surfaces were visible in slots No. 10 and No. 18. The failure of the conical part of the hub was confirmed as it matched the conical fragment found still attached to the engine after the event.

The examination determined that the hub failure was caused by a cracking process that originated in the part's subsurface. The origin of the crack was located practically in the center of slot No. 10 (see Figure 3, page 14), around 14 centimeters (5.6 inches) behind the front face of the hub and 1.4 millimeters (0.055 inches) below the surface of the slot bottom. No material quality (composition or microstructure) or manufacturing-related anomaly was found.

A region of fatigue striations, characteristic of low-cycle fatigue progression, was observed between the origin of the failure and the hub's inner face. The grains situated between the origin of the

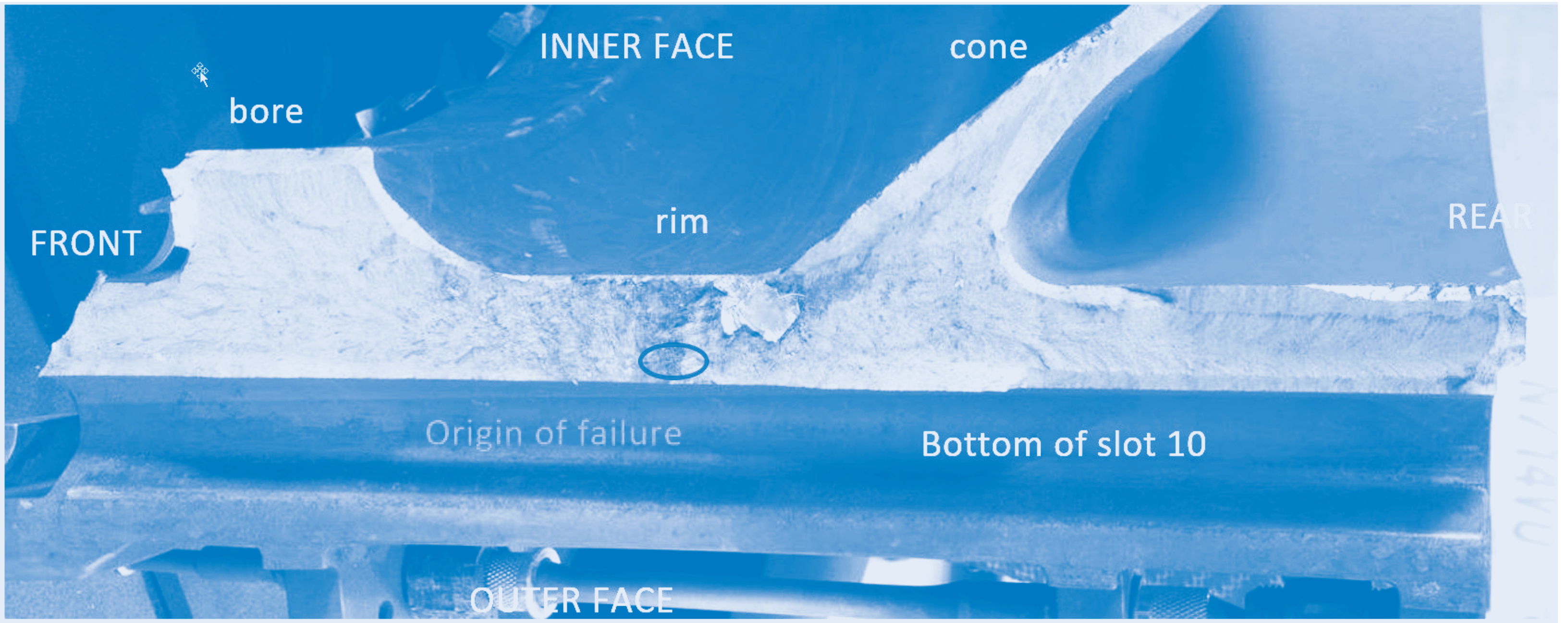

Figure 3. Fracture surface of slot No. 10.

failure and the surface of the slot bottom chiefly had near-cleavage facets (faceted growth) with the occasional presence of striations. A striation counting method already tested by P&W was used. The total number of striations was assessed at 1,652, which corresponds to the number of cycle of the stable crack propagation. It could also be observed that a little less than half of the stable progression of the crack, in number of cycles, occurred in a vacuum subsurface.

Based on the fractographic examination that revealed the presence of a large-faceted growth region, it was determined that the crack started in a microtextured region (MTR, also called a macrozone) 1.75 millimeters (0.069 inches) wide by 1.63 millimeters (0.064 inches) deep (see Figure 4).

A metallographic cross section was prepared by polishing lightly into the fracture surface. This cross section underwent an electron back scatter diffraction (EBSD) analysis at the end of which a grain orientation map was obtained. A strong correlation was found between the map showing a region with predominantly basal-oriented α grain, perpendicular to the hoop stress (dotted line in left image of Figure 5) and the location of the predominantly faceted region (dotted line in right image of Figure 5, page 16).

Pure titanium has a compact hexagonal crystalline structure at ambient temperature (α phase). The crystallographic indexes make it possible to indicate certain characteristics of this structure. Thus, the base plane, also called the basal plane, is indicated by its crystallographic index (0001). It is shown in Figure 6, page 17. The basal direction is the perpendicular direction to the basal plane (direction c[0001] in Figure 6). Due to its hexagonal structure, the α phase is intrinsically anisotropic at the crystalline level, which has significant consequences on the elastic and plastic properties of titanium and its alloys. The elasticity modulus of the α phase depends on the angle between the loading direction and the axis <c> of the crystalline lattice.

Above 882°C, titanium has a body-centred cubic structure (β phase) up to its fusion temperature, 1,670°C. Thus, when it is heated to above 882°C, it passes from the α phase to the β phase. The alloy content and the thermomechanical processing during manufacturing determine the morphology and the fraction of the α and β phases of the microstructure. The transition temperature from the β phase to the α phase is called β-transus (Tβ) and depends on the composition of the alloy. At ambient temperature, Ti-6-4 has an α/β two-phase structure with a small volume percentage of residual β.

P&W's classification of the MTR associated with the origin of the failure confirmed that it was, according to its experience, larger and more intense than the mean MTR statistics (maximum size of 1.1 x 106 μm2 and a maximum intensity of 6.58).

The metallurgical examinations of the fan hub fragment found that the engine No. 4 fan hub fracture was due to a cold dwell fatigue phenomenon. It originated in a macrozone where the orientation of the grains is unfavourable with respect to the (hoop) maximum stress direction in the middle of slot No. 10. The crack progressed around 19.7 millimeters (0.775 inches) before becoming unstable.

No material quality (chemical composition, microstructure) or manufacturing-related anomaly was found that could be associated with the area in which the fracture originated.

No evidence of damage arising from a maintenance activity was found on the front face of the hub in the vicinity of slots No. 10 and No. 18.

The various metallurgical and mechanical checks carried out during the investigation found that the material was consistent with properly processed Ti-6Al-4V alloy according to existing P&W requirements for rotor-grade material.

Lessons Learned from the Investigation

The in-service inspections carried out just after the accident found a number of fan hubs with surface damage, giving rise to a probable scenario linked to an

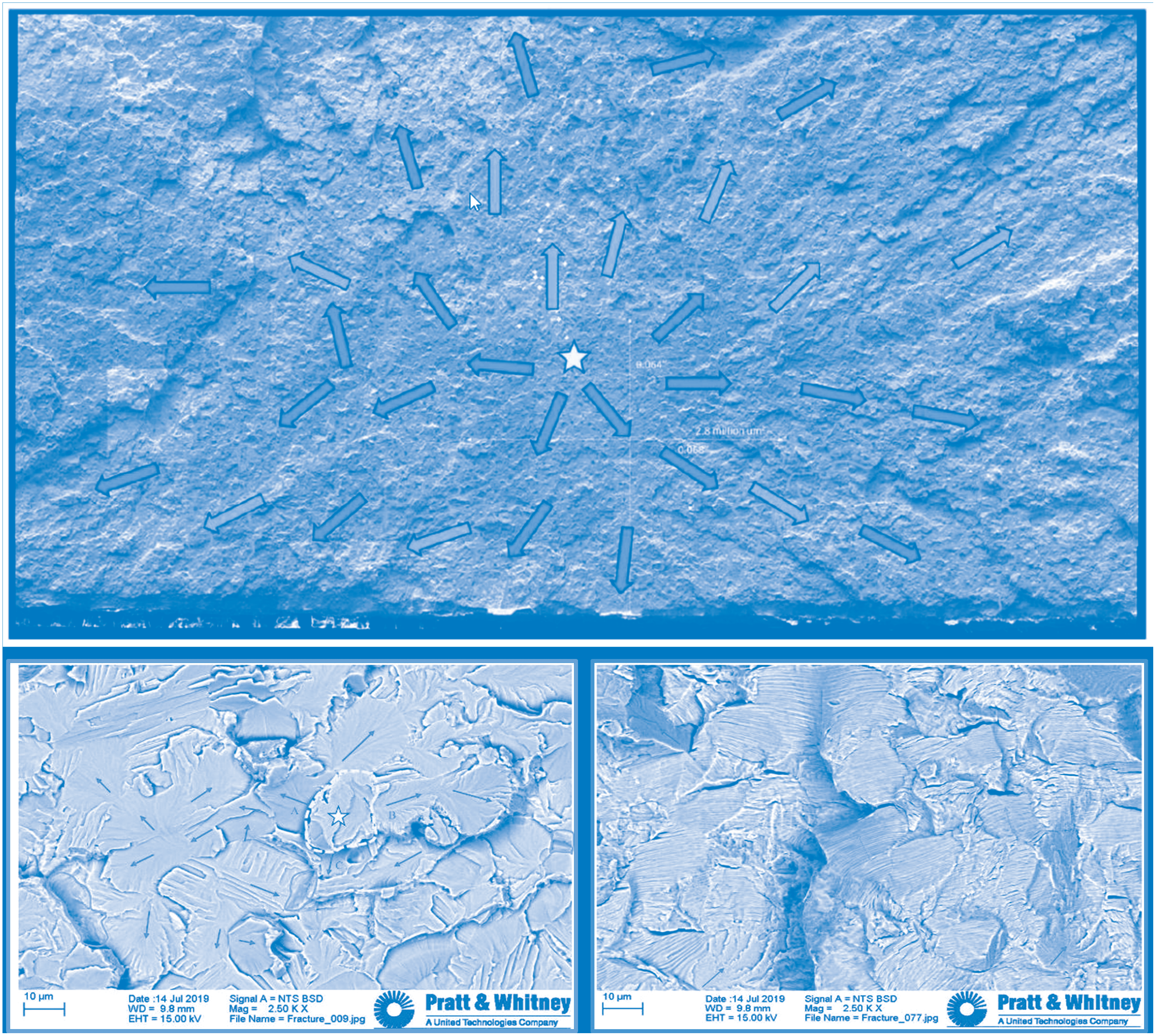

Figure 4: SEM detail view (top) of the origin fracture. The lighter arrows show the crack growth direction in the faceted regions, and the darker arrows show the growth direction in the striated regions. In the two lower images, areas where the striations are prominent, the orientations confirm the existence of a primary origin at 1.4 millimeters below the surface of the slot bottom (white star).

inappropriate maintenance operation.

The perseverance in carrying out the search operations to retrieve the missing fan hub fragments resulted in the finding and examination of a piece of fan hub debris 21 months after the accident. The results of the examinations invalidated the maintenance damage scenario considered the most likely up to this point and showed a failure mode, which was originally ruled out as it was considered as highly unlikely.

This failure mode had already been seen on other titanium alloys; however, no titanium Ti-6-4 hub had failed in service under cold dwell fatigue before this on commercial airplanes.

Up until this event, the titanium alloy Ti-6-4 was not considered sensitive to the cold dwell fatigue phenomenon. Certain alloys such as IMI 685 or Ti-6242 had already shown predispositions to this phenomenon in the 1970s, whereas Ti-6-4 had accumulated significant in-service experience without the occurrence of any incident identified as being linked to this phenomenon. Today the

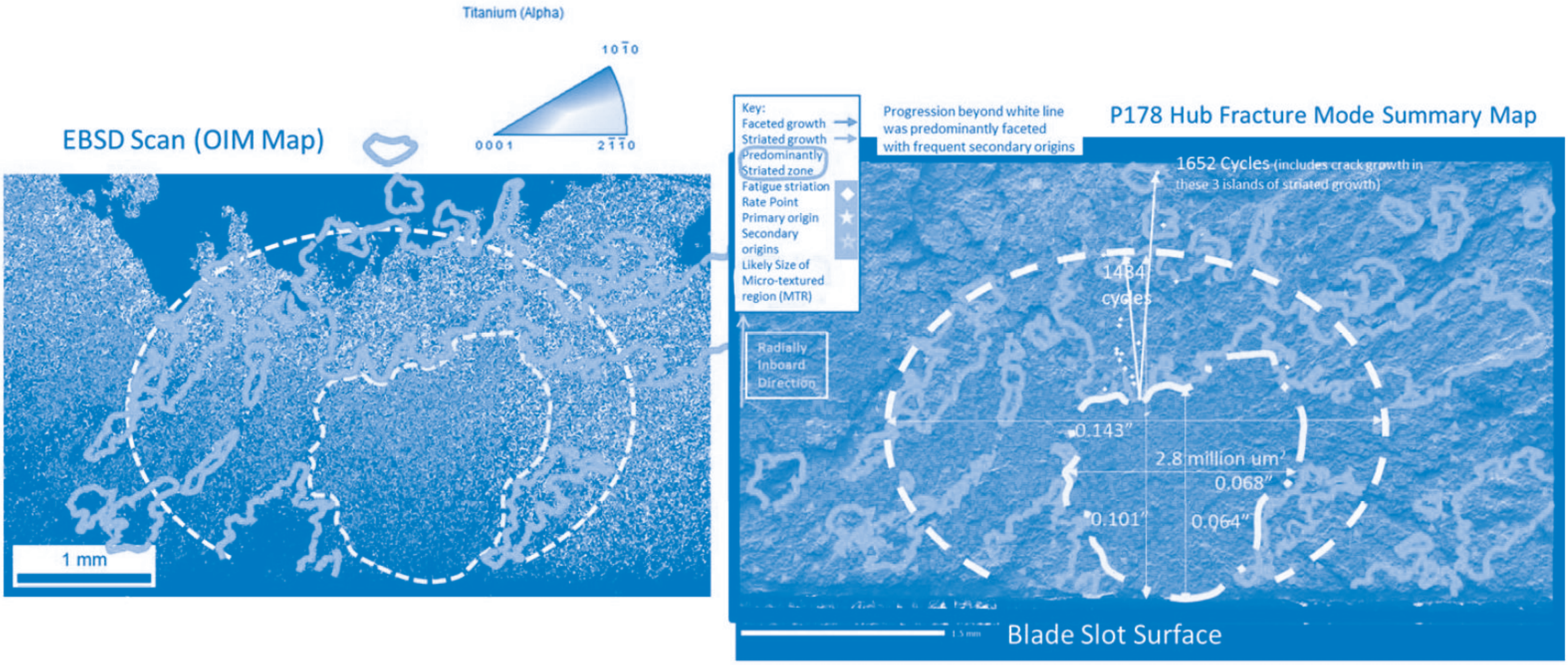

Figure 5: Micrograph of the fracture origin showing the crystallographic orientation map (on left) obtained with EBSD after light polishing into the fracture surface. The darker regions within the dotted lines correspond to grains that have their basil planes orientated perpendicular to the hoop stress direction through the hub rim. This orientation is conducive to crack initiation under fatigue. The regions with predominately near-cleavage facets (on right) and the macrozone prediction correspond to those regions where there is a high degree of basal-orientated grains. The striation areas exhibit a more random crystallographic orientation.

manufacturers are still studying titanium alloy Ti-6-4 cold dwell fatigue to fully understand the process that led to the F-HPJE fan hub fracture.

The investigation was able to show that the maximum stress level observed in the fracture zone of the F-HPJE fan hub (slot bottom) was less than 80% of the material's yield strength. The investigation also brought to light that the failure of the fan hub occurred after a number of cycles four times less than the hub's minimum life (3,500 vs. 15,000). The methods for estimating the pure fatigue life developed by the engine manufacturer and accepted by the FAA forecast an incipient crack at 20 times the number of cycles of engine No. 4, without considering the cold dwell fatigue. It was accepted that cold dwell fatigue was not significant at these stress levels.

However, the volume of the test specimens for cold dwell fatigue, along with the dwell times applied in tests, are not sufficiently representative of an actual part to activate large macrozones. In fact, to reduce test times, the specimens are subject to shorter dwell times and greater stress compared to actual parts. Lastly, the initiation of a cold dwell fatigue crack generally occurs in a macrozone. The probability of having an intense macrozone in a test sample is by nature less than in a larger part. The service life debits obtained by dwell effect during tests on specimens are, therefore, at the current time difficult to transpose to in-service parts.

A lack of knowledge of both the activation envelope of the cold dwell fatigue phenomenon on Ti-6-4 and the conditions conducive to the appearance of intense macrozones meant that a cold dwell fatigue crack was initiated at a stress level lower than that accepted up until now by only taking into consideration pure fatigue, and at a significantly lower number of cycles.

Manufacturing processes: Cold dwell fatigue cracks are initiated in macrozones, the presence of which is inherent to the manufacturing process of forged titanium parts. The macrozones generally appear during the process to convert an ingot into a billet and are then reduced during the subsequent forging process by means of various successive thermomechanical treatments.

The risk of macrozones appearing increases with the size of the billets. For small billets, the considerable plastic deformation (strain hardening) during the conversion and forging phases reduces the size and intensity of the macrozones. Large engines with a high-bypass ratio require larger diameter fan hubs to improve effectiveness. These hubs require larger billets and may not benefit from the same deformation levels as those parts that come from smaller billets. This may contribute to the risk of macrozones of a large size and intensity being present.

Production check: At the present time, it is not possible to detect in a reliable way the presence of macrozones using nondestructive methods, whatever the stage of the manufacturing process. The EBSD technique characterizes the grain crystallographic orientation and thus reveals a macrozone, but this is a destructive examination. The suspected zone must be isolated, removed, and prepared by polishing before the examination.

Methods for predicting the presence of macrozones in finished parts by digital simulation are starting to emerge but are

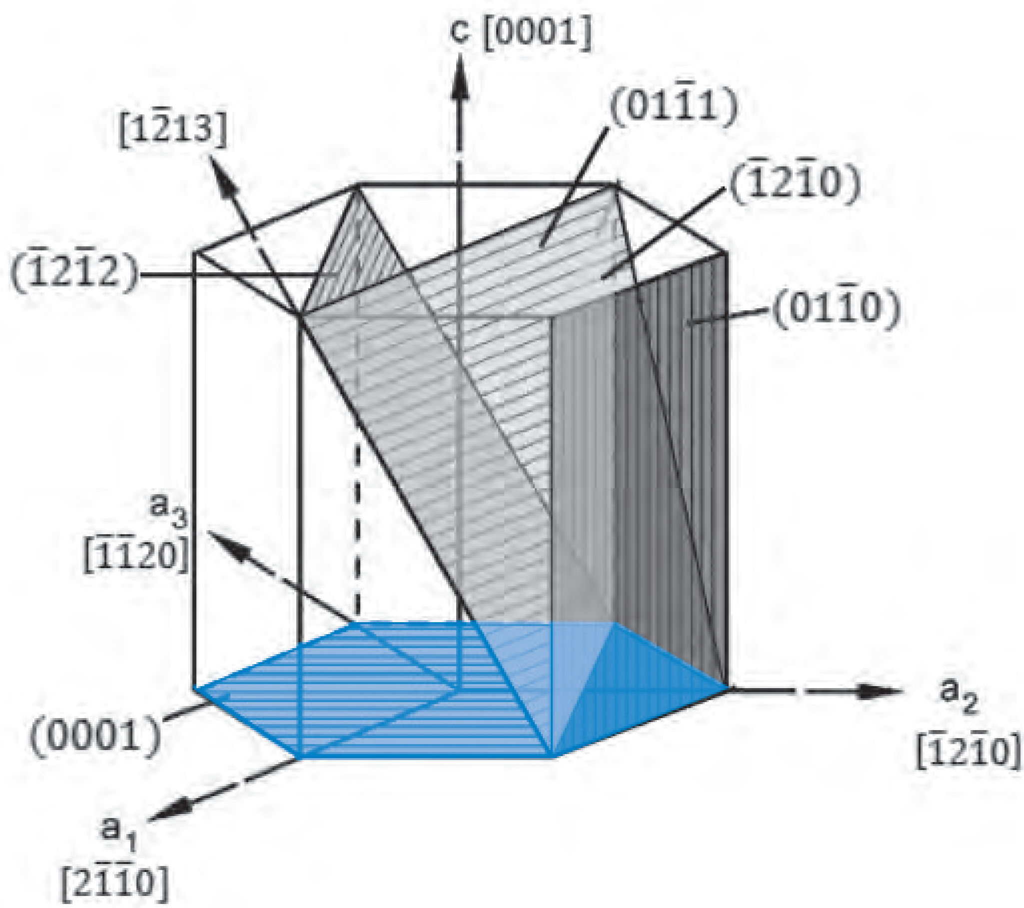

Figure 6. Crystallographic indexes of α phase, compact hexagonal structure.

not yet reliable enough. It is currently possible to predict macrozones in a test sample, but transposing this prediction to an actual part is still in progress.

Ultrasonic measurements are carried out during the part manufacturing process in order to principally detect α based type anomalies or process induced cracks. To date, the ultrasonic inspection method does not detect macrozones.

Thus, today, macrozones may be naturally present in forged critical parts made of Ti-6-4 and are not covered by rejection criteria as no reliable nondestructive detection method exists and because the current manufacturing processes do not reliably control the risk of them appearing.

The tendency to increase the size of engine fans to reduce engine fuel consumption may lead engine designers to try and substantiate higher acceptable stress levels in order to limit the weight of these engines. This may lead to an increase in the risk of a cold dwell fatigue incipient crack in a macrozone.

The size criteria during the design phase for forged critical parts made of Ti-6-4 should thus be adapted to improve the control of the cold dwell fatigue phenomenon, taking into account the risk of macrozones appearing in production—given that these macrozones may contribute to this phenomenon and the limits of the macrozone detection capabilities.

In-service monitoring: The presence of an intense macrozone in a titanium part not detected during production may lead to the initiation of a crack in service. The current nondestructive inspection methods detect subsurface cracks or voids.

The initiation of a cold dwell fatigue crack can only be predicted by taking into consideration both the characteristics of the macrozone (size, position, orientation, and intensity) and local loading (stress level, dwell time, and temperature). A crack may start in a zone with low stress due to the presence of an intense macrozone or due to the length of dwell time.

The continuing airworthiness of critical parts made of the titanium alloy Ti-6-4, which undergo a manufacturing process likely to lead to the presence of intense macrozones and for which the risk of failure due to a cold dwell fatigue phenomenon has not been sufficiently considered during design, may require the implementation of appropriate means to detect in-service cracks before the failure of the part.

The BEA issued two recommendations to certification authorities. The aim of the first recommendation was to ensure that work continues on understanding the dwell fatigue failure mechanism on α/β titanium alloys. The second recommendation was issued to ensure that an adapted in-service inspection program is implemented to detect possible incipient cracks that might lead to the failure, due to cold dwell fatigue, of in-service engine rotor-grade critical parts made of α/β titanium alloys. ◆

ISASI Kapustin Scholarship Essay

The following article is the third of three essays from the 2021 Kapustin Scholarship winners that were presented during ISASI 2021. The number of scholars selected each year depends upon the amount of money ISASI members donate annually to the scholarship fund. Details about scholarship applications and additional information can be found on the ISASI website at www.isasi.org. Application and essay deadlines are mid-April of each year.—Editor

Exploring New Ways of Investigating: **3-D Aviation Accident Scene Reconstructions**

By Yifan Wang, 2021 Kapustin Scholar, Cranfield University, Safety and Human Factors in Aviation, UK

(This article was adapted with permission from the author's Kapustin essay presented during ISASI 2021, a virtual seminar hosted from Vancouver, B.C., Canada, from Aug. 31 to Sept. 2, 2021. The theme for the seminar was "Staying Safe, Moving Forward."—Editor)

Introduction

With advances in software and hardware technologies such as photogrammetry and scanners, 3-D reconstructions of aviation accidents are also becoming possible. The reconstructed 3-D models have the potential to change the traditional accident investigation paradigm by allowing investigators to analyze the accident scene from a more macro and holistic perspective without having to physically visit the scene, by introducing more new technologies to assist in analyzing the cause and restoring the accident process, and by better preserving evidence at the scene after the accident and reducing the cost of accident investigation training.

This paper will analyze the challenges faced by accident investigators, discuss current methods of 3-D aviation accident scene reconstruction, and give examples of the combination of augmented reality (AR) and 3-D accident scene reconstruction, machine learning, and 3-D accident scene reconstruction to analyze their possibilities and potential for development to address these difficulties.

The Challenge for Investigators

Aviation accident investigation often requires the cooperation of multiple countries and agencies, so a great deal of time and money can be spent on the travel arrangements of investigation experts from all over the world (D'Anniballe et al., 2020). The global spread of COVID-19 is also a warning that the challenges investigation teams face are not only from the accident itself, but also from external factors such as the environment. The International Civil Aviation Organization (ICAO) has issued guidance on accident investigations under COVID-19, such as delay in readout of flight recorders by another state due to travel restrictions (Aircraft Accident and Incident Investigation, n.d.), but these measures are ultimately only stopgap measures and may complicate the accident investigation process.

However, with the increasing diversity of the investigation team, the need to adjust work schedules and travel itineraries, the increasing speed of information dissemination on the Internet, and the accelerated pace of life, the accident investigation team will be under pressure from the news media, stakeholders, and public opinion to analyze the causes of the accident and to give advice and recommendations more quickly. These challenges are impacting existing accident investigation methods.

3-D Aviation Accident Scene Reconstruction

The investigation of an aviation accident has three main objectives: data collection, data analysis, and presentation of the results of the analysis (ICAO, 2001). Accident scene reconstruction primarily places new demands on data collection and at the same time helps investigators to analyze data from a new perspective.

There are currently two main methods of acquiring data: 3-D laser scanning and 3-D photogrammetry. 3-D laser scanners are used to scan the accident site, forming a "point cloud" on the surface of the object and then using software to create a 3-D solid mesh. This technique is now maturing, with good solutions such as Leica (Boehler & Marbs, n.d.). 3-D photogrammetry is used to create 3-D models or scenes by taking photographs from different angles and overlaying them. For example, Hawkins in 2016 proposed a method for reconstructing 3-D models of aircraft accident sites using drones and photogrammetry (Hawkins, 2016).

D'Anniballe had proposed a combina-

Yifan Wang

tion of the two methods to reconstruct the accident scene. A 3-D map of the entire crash site (including the wreckage) is created using aerial photogrammetry and then a 3-D model of the wreckage components is created on the ground using a laser scanner (D'Anniballe et al., 2020). Even in the special case of an accidental aircraft that may sink into the sea, there have been studies on methods of acquiring data in water (Anwer et al., 2017).

As these technologies advance, the accuracy of 3-D accident scene reconstructions may also gradually increase, making it possible to analyze data with the help of 3-D accident scene models. Even in different accidents, there may be suitable solutions for building 3-D accident scene models.

AR Application with 3-D Accident Scene Reconstruction

AR is a situation in which real-world and virtual-world contents are combined dynamically (Billinghurst et al., 2014; Wu et al., 2013). This technology has given the aviation industry a boost and has been used in the design and manufacture of aircraft, navigation, maintenance, and other areas (Safi et al., 2019). A very good example is HoloLens, which is used for aviation maintenance. The advantages of applying AR technology to accident investigations have already been raised by experienced investigators (Sikkema, 2018). After the 3-D model of the accident scene is created in a virtual world, software such as Unity 3-D can be used to create a 3-D experience. And an iPad or HoloLens can be used as a platform to support the 3-D experience, enabling the accident scene to be reconstructed in a virtual environment and used for subsequent accident analysis (D'Anniballe et al., 2020).

The most obvious advantage of AR is the increased flexibility it allows for cooperation in accident investigations. The investigators do not need to travel long distances to a fixed meeting place, saving travel time and ensuring their safety. They do not need much contact with each other and do not have to touch the actual accident site. At the same time, by reconstructing the accident site in a virtual world, data can be stored for a long time and shared online, making information exchange and cooperation more fluid and rapid.

During the investigation, the data can also be updated at any time to supplement the investigator's knowledge of the overall accident scene situation. If new pieces or information are found missing during the wreckage cleanup process, they can be superimposed on the 3-D model at any time, although this may take more time to recreate the model.

The other advantages of AR in accident investigation are the long-term preservation of accident evidence and the reduction of investigator training costs. Evidence at an accident scene could be damaged to some extent by secondary fires, local weather (e.g., rain may damage ground evidence), or even human factors, and the destruction or loss of evidence can have an impact on the analysis of the cause of the accident.

However, if the accident scene can be scanned and reconstructed in a timely manner, a large degree of evidence can be preserved for ready analysis by investigators. At the same time, the preserved scenes can be applied to investigator training after a simplification process, which eliminates the need to reconstruct accident scenes for investigator training, protects the safety of instructors and students, and reduces the cost of training (Sikkema, 2018).

Machine Learning and 3-D Accident Scene Reconstruction

Machine learning can build models based on sample data (known as "training data") in order to make predictions or decisions without being explicitly programmed, and this technique is now used in a wide range of disciplines (Jordan & Mitchell, 2015). In combination with 3-D accident scene reconstruction, machine learning could be used to improve the accuracy of models (Rusu et al., 2009) and to assist in the analysis of accident processes.

In the event of a crash, conducting an accident scene reconstruction is a process of analyzing the motion of an aircraft during a crash sequence and calculating the acceleration of the aircraft during the principal impact. In the field of traffic accidents, the use of 3-D modeling to analyze the process of a car impact and the forces applied is now well established (Zhang et al., 2008). In the field of aviation, Michael carried out a study in 2009 to calculate the acceleration of the aircraft during the impact, so it is possible to reproduce the loading process by calculating the flight data found in the aircraft recorder (Dobbs, 2010). But at the same time this work is heavily programmed and computationally demanding. If machine learning can be used to build a model for analyzing aircraft impact attitudes using past accidents or tests as training data, it has the potential to effectively improve the efficiency of future accident investigations.

Conclusion

By creating a 3-D accident scene model, the information from the actual accident scene is converted into data and information in the virtual world, which means that the 3-D model could be a new platform for accident investigation. The model can be projected into the actual space again through the combination of AR technology, creating a "scene" for investigators to investigate accidents anytime and anywhere.

The data can be stored for a long time and used in subsequent investigator training to protect the safety of students and reduce training costs. Then, through a combination with machine learning, past accident scenes data could be data-mined and used as a training set to build analytical models, which can help to assist in the analysis of aircraft impact attitudes and restore the aircraft accident process in subsequent accident investigations.

These two are just examples of the further applications of 3-D accident scene modeling, which may also bring additional benefits to accident investigations if other techniques and models can be combined in a sensible way. Although the technology is not yet mature, as technology advances, it is believed that 3-D accident scene reconstruction and further applications could be an effective solution to the challenges faced by investigators. ◆

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The Self-Administered Interview:
A Case Report from a Helicopter Crash

By Dr. Ajiri Ikede, Physician and Aviation Accident Investigator, Canadian Armed Forces, and Dr. Ronald Fisher, Professor of Psychology, Florida International University

Ajiri Ikede

Ronald Fisher

(This article was adapted with permission from the authors' technical paper presented during ISASI 2021, a virtual seminar hosted from Vancouver, B.C., Canada, from Aug. 31 to Sept. 2, 2021. The theme for the seminar was "Staying Safe, Moving Forward." The full technical paper, The Self-Administered Interview: Case Report from a Helicopter Crash*, is available on the Society's website, www.isasi.org, in the Library section under the Publications and Governance/Technical Papers tabs.—Editor)*

Introduction

Following an aviation accident, investigators attempt to gather relevant information from physical sources and human beings. We focus here on human sources, given that interviewing witnesses remains a cornerstone of most investigations. To facilitate witnesses providing information, research psychologists have developed an interviewing protocol, the Cognitive Interview, that is based on the science of memory retrieval and communication. The Cognitive Interview has been tested rigorously in the past 30 years and has been found to reliably increase the amount of information witnesses report in dozens of controlled laboratory studies. More recently, the Cognitive Interview was used in several field studies of highly arousing experiences (vehicular accidents, crimes, terrorist acts) and has been found to elicit considerably more information than conventional interview protocols.

Optimal use of the Cognitive Interview entails conducting a face-to-face interview shortly after a critical event, as delaying the interview will cause witness memories to fade and/or to be less accurate. Aviation accidents, however, often occur at remote locations, which inevitably leads to a delay between the time of an accident and when the first in-person interview of witnesses can be conducted. Our goal, therefore, was to adapt the Cognitive Interview so that it could be implemented shortly after the accident.

We incorporated the Cognitive Interview's instructions and questions into a booklet format that could quickly be made available to witnesses, thereby allowing them to report their information shortly after the accident while being guided by the scientific principles of memory retrieval and communication. A self-administered interview (SAI), when completed shortly after a critical event, has been shown to enhance witness memory in criminal investigations and is being used by various law enforcement agencies. We therefore adapted the SAI for an aviation event to be used by aircraft accident investigators. This adaptation occurred in early 2020 and was a collaborative effort between members of the Directorate of Flight Safety (DFS) in Ottawa, Ont., Canada, and one of the co-developers of the SAI, Dr. Ronald Fisher.

In April 2020, DFS received notification of a helicopter crash in the Ionian Sea. Due to restrictions associated with the ongoing COVID-19 global pandemic, there would have to be a delay of at least 72 hours between the time of the accident and the arrival of the investigators to begin witness interviews. As per current flight safety protocol within the Royal Canadian Air Force (RCAF), witnesses of the accident were asked to give a written statement that was collected by the flight safety officer (FSO) who was on scene.

In addition to this standard protocol, it was determined that the newly adapted SAI may be of some benefit. Therefore, a draft copy of the SAI was forwarded to the FSO for distribution to the witnesses. This resulted in two sets of statements that were now available for the investigators to review prior to arriving in Italy for in-person interviews. This unique situation also provided an unprecedented real-life situation in which the data obtained from an individual witness from a general witness statement (GWS) could be compared directly to the data obtained from the same individual using the SAI. The head-to-head comparison of a GWS and an SAI could shed some light regarding the "best practices" used by investigators for obtaining written statements from witnesses and has the potential to shape how future investigations are conducted.

Materials and Methods

Witnesses were initially asked to complete a GWS within 24 hours of the accident as per the usual flight safety standard operating procedures. They were subsequently asked to complete the SAI the next day once the tool became available to the FSO. A total of 20 GWSs (from Day 1) and 20 SAIs (from Day 2) were completed and reviewed by the investigators. In order to be included in the analysis, witnesses must have completed both a GWS and an SAI. One witness completed the GWS digitally and simply copied the statement and pasted it into the SAI. These two documents were excluded from the analysis, leaving 18 pairs of statements that met the inclusion criteria for analysis.

All written statements were carefully redacted to maintain anonymity and then transcribed to Word documents. Once in digital format, software was used for quantitative and qualitative analysis. The SAI and GWS were compared by looking at the differences between each group of the witness statements, as well as the differences between each individual's responses when using both tools. Quantitative analysis of the statements compared the total number of words, while qualitative analysis explored the number of words that were associated with certain themes. Themes were selected through collaboration with human factors analysts and were defined as categories that described relevant aspects of the narrative in the witness statements. The themes used in the analysis were

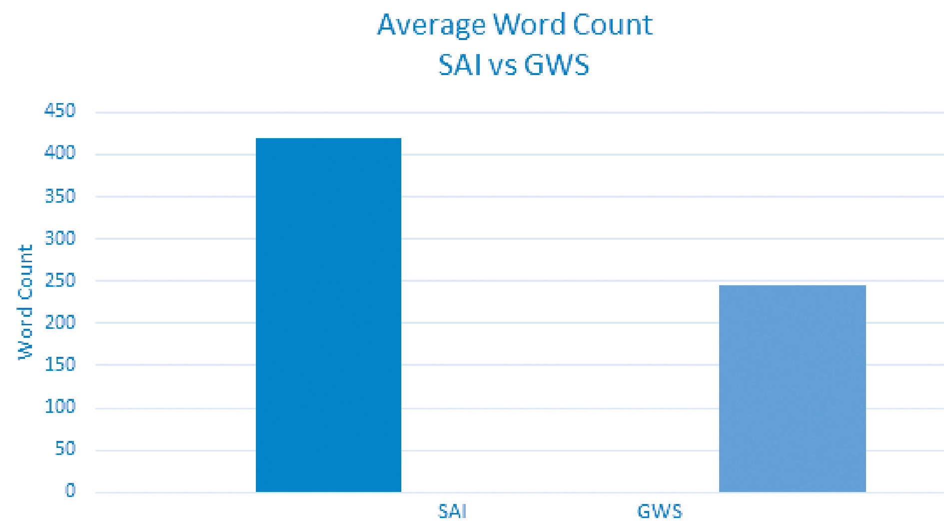

Figure 1. Average of total word counts from SAIs and GWSs.

Themes	Key Words Used in Search
Environment	sea, wave, choppy, rough
Senses	smell, sense, jet propellant 5, fuel, hear, saw, sound, loud
Emotion	fear, afraid, shock, drill, exercise, emergency, alarm, scared, worried, cry, upset, real heart, feel
Lighting	sun, sunset, dark, light, smoke, flare
Impact	crash, impact, attitude, nose, bank, speed, kts, knots, whip, whiz, altitude, disintegrate, shatter, ditch
Memory	remember, recall, believe, think, thought
Casualties	drew, pax, passenger, survivor, body, remains, entrails, search, casualties, casualty
Damage	debris, part, component

Table 1. Key Words Used to Categorize Themes

emotion, lighting, memory, impact, environment, damage, casualties, and senses. Each theme consisted of key words that were counted as they appeared in the statements. Table 1 shows a list of all the words that were included in the search for each theme.

Results

The average number of words in the GWS was 246 (median = 216.5) and ranged from 107 to 593. The average number of words in the SAI was 420 (median = 397.5) and ranged from 106 to 1,018 (see Figure 1). The SAIs showed a 70.7% and 83.6% increase in the average and median number of words, respectively. The SAIs had a total of 441 theme words compared to GWSs' 243 (see Table 2) with a consistently higher total across each theme. All but two witnesses wrote more information in the SAI than in the GWS. Furthermore, all but one witness provided equal or more theme words in the SAI than in the GWS. The average number of theme words per witness for the SAI (22.5) was almost twice as much as for the GWS (11.5) with all but one witness

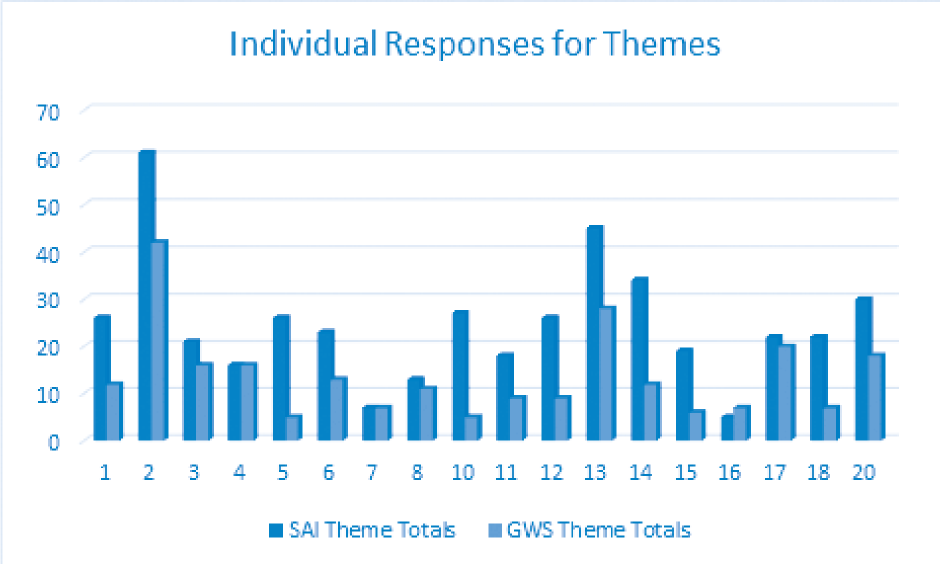

Figure 2. Comparison of usage of theme words in individual responses between SAI and GWS.

Themes	SAI	GWS	%Change from GWS to SAI
Environment	11	5	+120%
Senses	61	36	+69%
Emotion	64	25	+156%
Lighting	50	21	+138%
Impact	100	73	+37%
Memory	52	9	+478%
Casualties	67	49	+37%
Damage	36	25	+44%
Total	441	243	+81%

Table 2. Key Words Found in SAI and GWS

providing more theme words in the SAI (see Figure 2).

Discussion

That the SAI gathered considerably more information than the traditional GWS procedure tells only part of the story. There are several other benefits accrued from using the SAI. First, the SAI questions were asked in the same systematic order to all witnesses, so their answers to a specific question were easy to find (e.g., the answer to the last question was at the end of the response sheet). By comparison, the witness responses in the GWS were scattered throughout the response sheet, making it more difficult for investigators to search for specific information. Also, the systematic nature of the SAI made it easier to compare many witnesses' answers with one another to see if the witness responses converged on one conclusion. This is usually a good indicator of the accuracy of a response.

Sometimes witnesses draw sketces to represent their experiences, and these sketches are often very informative, as they convey spatial information more readily than verbal descriptions. Although sketches are helpful, not one witness drew a sketch voluntarily when completing the GWS. By comparison, all of the witnesses who completed the SAI provided a sketch.

To maximize investigative efficiency, investigators should conduct face-to-face interviews with the most informative witnesses first before interviewing less-informative witness, as witness information will be lost over time and the potential loss due to delay is greater for more informative witnesses than for less informative witnesses. Examining the rich output of an SAI allowed investigators to infer which witnesses were potentially more informative than others. One of the benefits of the SAI was that it facilitated investigators making triage decisions of which witnesses to interview immediately and which witnesses could be interviewed later.

Finally, the output of the SAI allowed investigators with clinical insights to make more informed judgments about which witnesses needed more emotional support than others as inferred from the increased number of "emotional" theme words in the responses. The richer output in the SAI thereby allowed clinicians to make judgments about providing appropriate support to those who may have been exposed to and adversely affected by a traumatic event.

This was a retrospective observational analysis with the purpose of quality improvement with regard to collecting information from witnesses. As such, there was no predetermined null hypothesis nor established statistically significant differences between the SAI and GWS. Given the nature of the accident, some details provided by the witnesses could not be objectively verified. Of the statements and observations that could be verified, almost all were consistent with the findings of the investigation. Notwithstanding these limitations, the SAI demonstrated a clear advantage over the GWS by all objective measures.

For those interested in incorporating the SAI into their investigation procedures or for more information, please contact Dr. Ronald Fisher (fisherr@fiu.edu) or Dr. Ajiri Ikede (AJIROGHO.IKEDE@forces.gc.ca). ◆

AS332L HELICOPTER ACCIDENT:

HOW DID THE TAIL ROTOR SEPARATE?

(This article was adapted with permission from the author's technical paper presented during ISASI 2021, a virtual seminar hosted from Vancouver, B.C., Canada, from Aug. 31 to Sept. 2, 2021. The theme for the seminar was "Staying Safe, Moving Forward." The full technical paper, Helicopter Accident of AS332L, Occurred on Nov. 8, 2017, in Japan: How Did the Tail Rotor Separate? *is available on the Society's website, www.isasi.org, in the Library section under the Publications and Governance/Technical Papers tabs.—Editor)*

By Okuyama Katsuya, Japan Transport Safety Board

OKUYAMA KATSUYA

On Nov. 8, 2017, the Aerospatiale AS332L crashed in Ueno Village, Gunma Prefecture, in Japan due to the separation of the tail rotor and loss of control during the flight. This presentation will focus on the following topics:

- Summary of the accident.
- How the tail rotor separated during the flight.
- Human factors analysis of maintenance.
- Accident prevention measures.

Figure 1. Wreckage of JA9672.

Summary of the Accident

On Nov. 8, 2017, Toho Air Service's Aerospatiale AS332L JA9672 crashed onto the bridge in Ueno Village, Gunma Prefecture. The helicopter was used to transport heavy goods by a cargo sling. On the day of the accident, after the goods transportation in Yamanashi Prefecture was completed, the aircraft was flying to Tochigi Heliport for a ferry flight. During flight at an altitude of about 6,800 feet and a ground speed of about 150 knots, reduced speed occurred after a large vibration, and the helicopter descended by autorotation and flew to a landing area

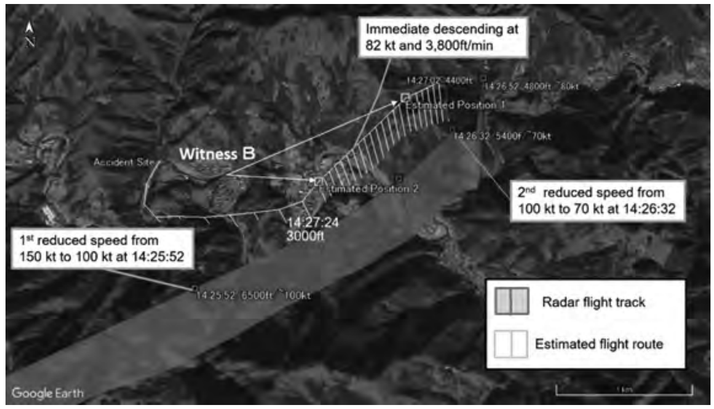

Figure 2. Immediate decent of the aircraft during emergency operation.

on the riverside. The helicopter leveled off at a low altitude, and the pilot attempted an emergency landing. Prior to the final approach, loss of control occurred due to a separated tail rotor, and the helicopter crashed on the bridge. A fire broke out, and four crewmembers were killed.

Why Did the Tail Rotor Separate?

Due to the breakage of the spindle bolt, the rotating tracking of the tail rotor was displaced, causing abnormal vibration and excessive load resulting in the tail rotor separating.

It is highly probable from the statements of the witnesses that the tail rotor separated from the airframe after the helicopter made a noise while turning to the right about 200 meters short of the riverside. Thereafter, the helicopter became uncontrollable, whirled to the left, and experienced a significant nose-down pitch as shown in Figure 4. It is probable that the helicopter at that time performed a nose-up maneuver in response to the nose-down pitch. It is also highly probable that the maneuver caused the main rotor to lean backward, which resulted in the tail boom being cut and the pylon and the horizontal stabilizer dropped. It is also highly probable that the helicopter immediately crashed after the nose touched down, cutting electric wires and leaking fuel catching fire.

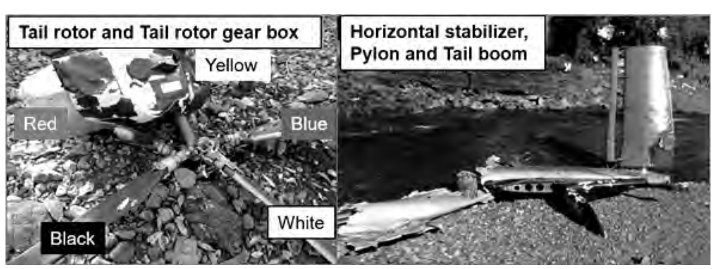

Figure 3. Separated tail rotor, horizontal stabilizer, pylon, and tail boom.

Was the Pilot Aware of the Vibration of the Tail Rotor?

The pilot appears to have been completely unaware until the first vibration. According to radar track and witness information, he was flying at an altitude of 6,500 feet at an airspeed of about 150 knots, which is close to the never-exceed speed (Vne). From the first signs, it is probable that the pilot slowed down sharply, discovered a large area of the riverbank below, lowered the main landing gear, and attempted an emergency landing. The location where the tail rotor separated was about 200 meters from the selected emergency landing site. If the tail rotor separation was delayed by about 30 seconds, the helicopter may have reached the emergency

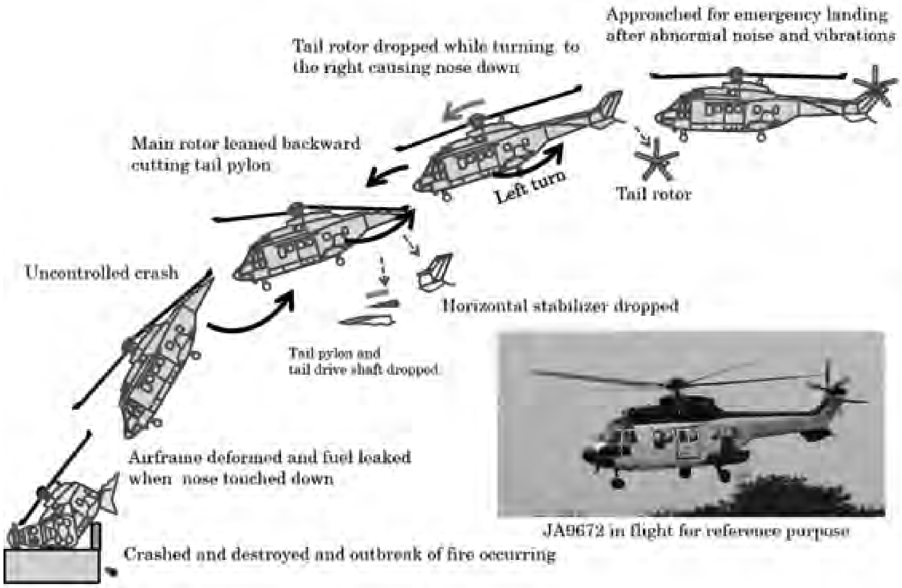

Figure 4. Changing flight attitude before the crash.

landing site. Also, during flight 3 days before the accident, low-frequency lateral vibration was observed by another pilot, but it was overlooked because it seemed to be due to an oil leak in the main rotor, which would be inspected at the next scheduled maintenance.

How Did the Spindle Bolt of Tail Rotor Flapping Hinge Fracture?

- *Function of tail rotor flapping hinge:* The five tail rotor blades and the tail rotor hub are connected by a spindle, and the flapping hinge acts as a hinge in the flapping direction of the connection. There are an inner ring and an outer bearing around the spindle bolt of the connecting part, and the inside is lubricated with grease and moves in a flapping direction according to the high-speed rotation of the tail rotor.
- *Detailed examination of spindle bolts and inner rings after the crash:* The spindle bolt of the white blade showed a fatigue fracture generated by cracks with two initiating points as shown in Figure 7. H1 crack with the initiating point at the bolt head propagated in the direction of 45 degrees. T1 crack propagated in the direction perpendicular to the axis and fractured the bolt. The inner ring was found in a fractured condition together with many fragments as shown in the center of Figure 7 (see page 26). A partial restructuring of the inner ring indicated that the fractured sections of the inner ring lost some fragments equivalent to 8% in weight. Each needle bearing was observed fretting and worn at different levels of damage as shown at the bottom of Figure 7, and several pieces were in fracture spalling. The most damaged area of the outer bearings was due to false brinelling wear and spalling peeling.
- *Spindle bolt rupture mechanism:*

  1. Under normal operating conditions with sufficient lubrication, the needle bearings move smoothly, and no torsional load is generated.
  2. When the needle bearing is fixed, the inner ring is fixed to the needle bearing and the inner diameters of the spindle bolt and the inner ring slip.
  3. In addition, when the spindle bolt is fixed, the load is concentrated on the contact surface while the spindle bolt and the spindle bush slide. In the case of the helicopter, a torsional load was generated, and the spindle bolt cracked and broke.

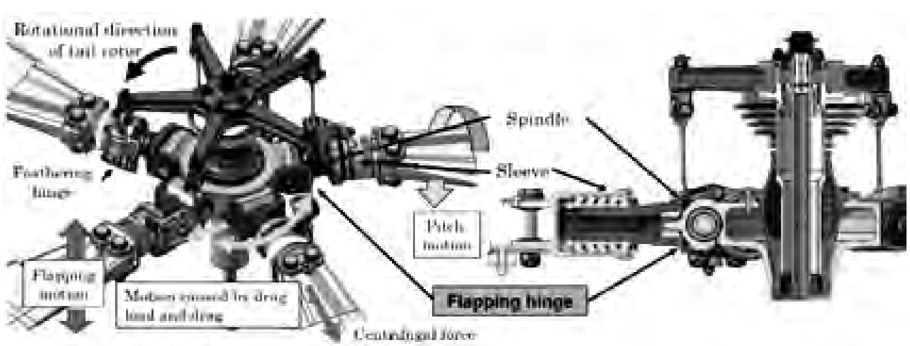

Figure 5. Structure of tail rotor.

Human Factors Analysis of Maintenance

- Required maintenance and inspection of flapping hinges:

  1. 1,000 hours: Check spalling and brinelling regarding needle bearing and inner ring.
  2. 500 hours: Check no locking and sealing by visual inspection.
  3. 50 hours: Check excessive binding points by the feel check of hinge, and check excessive play in drag plane (=< 0.6 millimeters).
  4. 10- hour preflight inspection: Check general condition, grease lubrication.

- Maintenance History of Flapping Hinges

  1. In May 2017, in the 1,000-hour inspection, the spindle bolts were rusted, so they were polished and reattached. There were no other abnormalities, but the seals were not replaced.
  2. In July 2017, a lot of black grease came out from the white blade during the 50-hour inspection.
  3. In August 2017, the play of the white blade increased in the 50-hour inspection.
  4. On Sept. 23, 2017: 94 flight hours before the crash, the white blade left having play, so a flapping hinge inspection was conducted and only the inner ring was replaced. The old inner ring was crushed, and the condition of the outer bearing was not confirmed. Also, the detailed condition of the old inner ring was not reported anywhere.
  5. On Oct. 30, 2017, another pilot pointed out low-frequency lateral

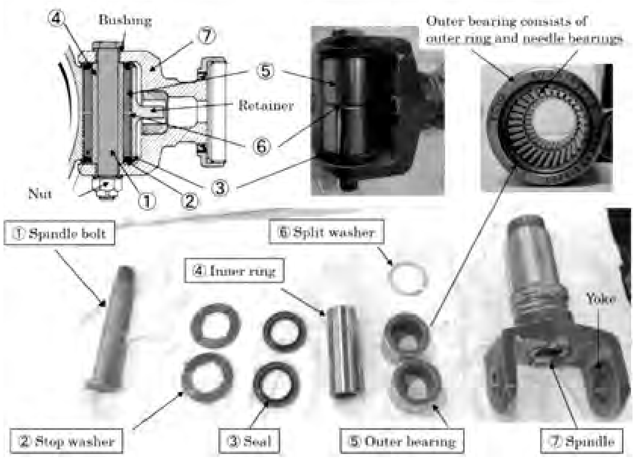

Figure 6. Tail rotor flapping hinge parts.

vibration, but it was judged to be the effect of an oil leak in the main rotor.

- Why Was Improper Maintenance Done?

  It was discovered early on that improper maintenance work on September 23 led to the breakage of the spindle bolts. The Human Factors Analysis & Classification System (HFACS) was used to analyze potential unsafe factors as to why such maintenance was carried out.

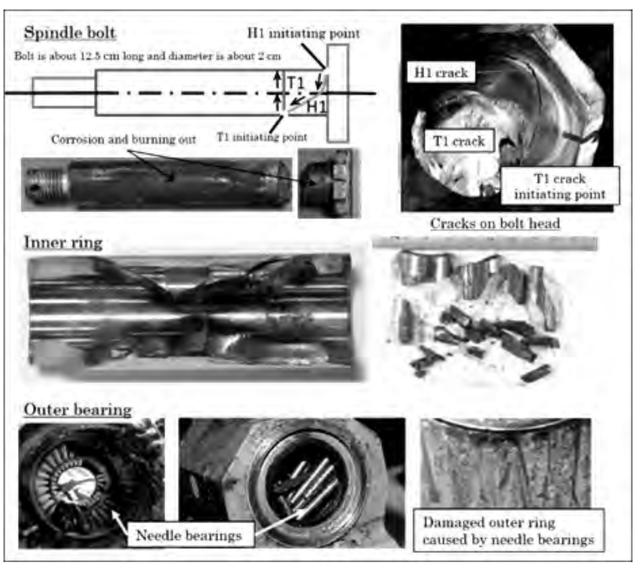

Figure 7: Detail of spindle bolt, inner ring, and outer bearing.

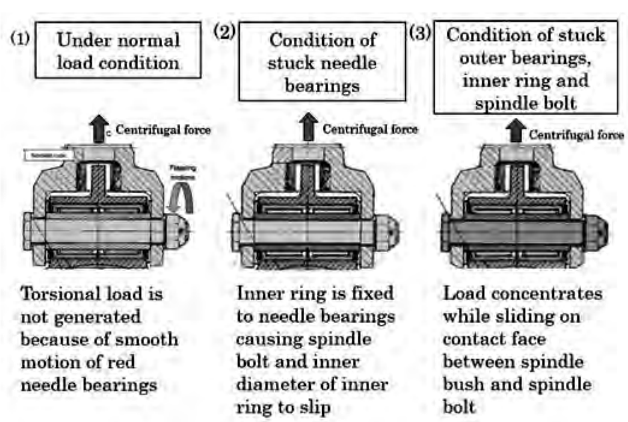

Figure 8. Spindle bolt rupture mechanism.

I. Stage 1: Unsafe Acts

- Errors (decision errors or perceptual errors)
  - The seal was not replaced when inspecting the flapping hinge.
  - Checked the crushed inner ring, and only the inner ring was replaced.
  - No inspection of the outer bearing was carried out.

II. Stage 2: Preconditions for Unsafe Acts

- Environmental Factors
  - When replacing parts, the lead time to receive them from the manufacturer must be taken into consideration.
  - The company did not own a special tool to replace the outer bearing.
- Condition of Operators
  - The certifying mechanic managed the schedule for transporting goods.
  - The certifying mechanic had been on board all flights for the past year and had been in charge of managing all maintenance work.
- Personal Factors
  - Insufficient CRM. Other mechanics couldn't recommend their opinion to a certifying mechanic.

III. Stage 3: Unsafe to Supervision

- Inadequate supervision
  - All maintenance work related to this aircraft was entrusted to a certifying mechanic and was not sufficiently supervised.
  - The crushed inner ring was discarded. The mechanic did not report the details of the defect to the company.

IV. Stage 4: Organizational Influences

- Resource Management
  - Accident helicopter was the only aircraft that was used to transport heavy goods in the company.
- Operational Process
  - The designer/manufacturer was not informed of the crushed condition of the inner ring, even though damage not described in the maintenance manual was found.
  - The company did not request the certifying mechanic to report details on the malfunction of the inner ring.

V. Certifying Mechanic Normalcy Bias

- It is possible that the certifying mechanic's maintenance decision on September 23 had a normalcy bias that he would be able to manage by replacing the inner ring until the regular maintenance in December.
  - He knew that extending the maintenance period would make it difficult to adjust the flight schedule.
  - In order to replace the outer bearing, it was necessary to extend the maintenance period.

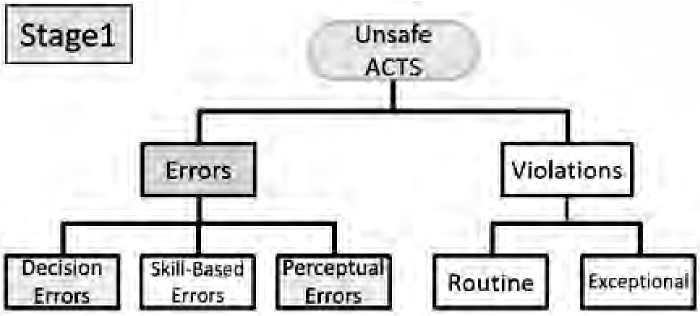

Figure 9. Stage 1 Unsafe ACTS.

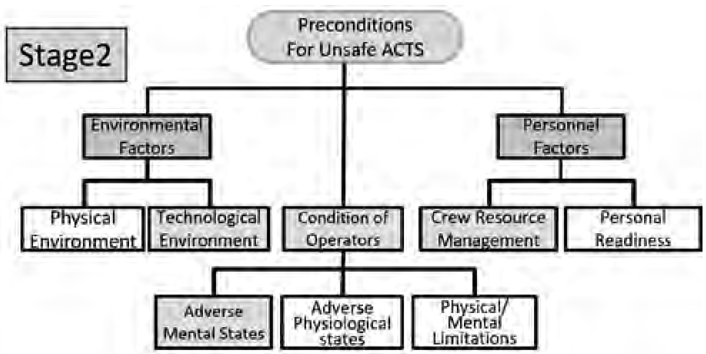

Figure 10. Stage 2: Preconditions for Unsafe Acts.

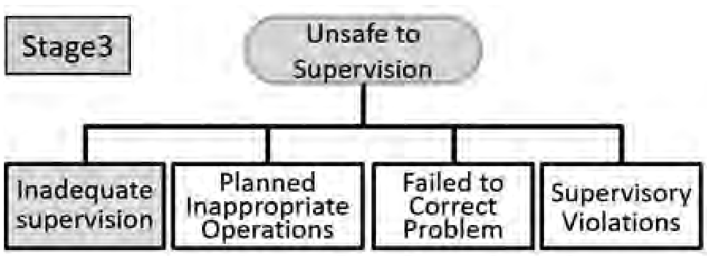

Figure 11. Stage 3: Unsafe to Supervision.

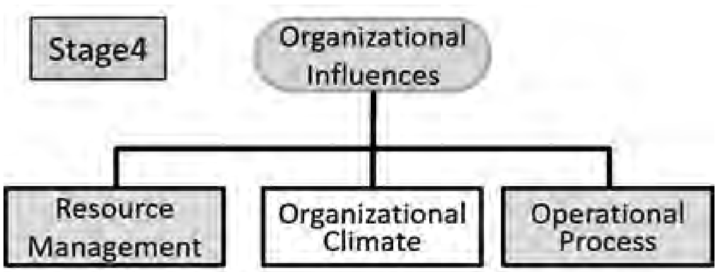

Figure 12. Stage 4: Organizational Influences.

Why Did Only JA9672 Have a Problem that Led to Breakage?

An emergency inspection of the flapping hinges revealed cracks and damage from aircraft of the same type around the world, but no serious damage like JA9672. The company had a record of operating the AS332L from 1985 and had the following characteristics related to grease:

- The grease used was changed in 2008, and the precautions for use in hot and humid conditions were not observed. But similar problems did not occur for about 10 years.
- According to maintenance records and parts billing records, the rubber seal had to be replaced when the flapping hinge inspection was performed, but it has not been replaced since at least the 2016 regular maintenance.
- Since it is possible that the grease lubrication was insufficient after the flight work was completed, the flight time and nighttime parking status of the aircraft and the temperature and humidity of the parking location were compared. Although the reason why the problem occurred only in the white blade could not be identified, the additional lubrication of grease during high temperature and humidity was not carried out regardless of the precautions from the manufacturer.

Accident Prevention Measures

It is probable that this accident would not have occur if all related parts were replaced during the flapping hinge inspection on September 23. Accident prevention measures are as follows:

- Regulatory agencies/design manufacturers:

1. Emergency inspection.
2. The inspection of the flapping hinge was changed from 1,000 hours to 250 hours.
3. Furthermore, based on the final inspection of the emergency inspection, it was decided to replace all the components related to the flapping hinge except the spindle with new ones within 250 hours.

- Operating company:
  1. Reinforcement of safety awareness and implementation of compliance education.
  2. Reconstruction of safety management system.
  3. Reconstruction of maintenance system.
  4. Review of regulations related to the entry in the flight logbook.

Recommendations

Japan Transport Safety Board to the company:

- Notification to the design manufacturer when damage not described in the manual is found and implementation of defect countermeasures based on technical examination.
- Promptly conduct a technical study on the information regarding maintenance precautions, etc., notified by the design manufacturer, etc., and inform the mechanic at the site.
- Finally, in conducting this accident investigation, many of the company's mechanics frankly responded to interviews to prevent accidents, which contributed to the analysis of human factors. ◆

NEWS ROUNDUP

ISASI Holds Top Officer Elections

Acceptance of nominations for the positions of ISASI president, vice president, secretary, treasurer, international councilor, and U.S. councilor closed on June 10 and the election will take place between June 15 and August 15. Election results will be posted on the Society's website and a notice will be sent to all members. ◆

ESASI Holds Seminar in Budapest

With great anticipation, the European aviation safety community prepared to travel to Budapest, Hungary, for the long-planned (and much-postponed) European Society of Air Safety Investigators (ESASI) seminar "Maintaining the Momentum" held April 6–7. This was the the first ESASI in-person meeting since Derby, England, in 2019 and had been originally planned and booked for spring 2020. That date was rescheduled at least four times due to COVID restrictions with the venue hotel (the Ensana Thermal Spa Hotel on Margaret Island in the Danube) helpfully bumping forward the reservation and terms and conditions each time.

The planning of the event, going back to 2020, had been well supported throughout by the Transportation Safety Bureau (TSB) of Hungary, led by Director Lorand Beckse under the Ministry for Innovation and Technology. This was useful as, like Derby in 2019, the main ESASI seminar was preceded on April 5, back-to-back, by the ACC/56 meeting of the European Civil Aviation Conference (ECAC) "Air Accident and Incident Investigation Group of Experts." This boosted attendance at both ESASI and ECAC events—as did holding a further meeting on April 5 of the Military Air Safety Investigation (MASI) group.

Despite some misgivings with the disturbing events in neighbouring Ukraine in the preceding weeks, the seminar preparations worked well with good IT support from the UK Air Accidents Investigation Branch. Health and travel restrictions were being lifted throughout Europe, the hotel staff was excellent, and attendance was very good, and there were close to capacity (110-plus) delegates for ESASI and a number of companions making the trip. The program followed the established ESASI seminar format with a day-and-a-half of technical presentations and updates—a total of 14, generally of 30 minutes' duration including Q&A time. The moderators kept the presenters to time, which gave excellent networking breaks for delegates between the presentations.

Details of the presentations, all well received, can be found on the ESASI website. They included a wide range of topics—an update by Airbus and the European Union Aviaton Safety Agency (EASA) on 5G issues in relation to air safety, 3-D photogrammetry on helicopter sites, general aviation in Hungary, military and civil investigations in Norway, parachute accidents in Sweden, and proposals for improved flight safety at general aviation airports everywhere. Perhaps the most striking presentation was an extended session by Jurgen Whyte of the Irish Air Accident Investigation Unit on the search-and-recovery challenges of the S-92 coastguard helicopter that crashed at Black Rock some years ago and the lessons learned. Part of the joy of the whole in-person atmosphere was the way that discussion of these presentations would spill into the tea and coffee and lunch breaks.

During the gathering, ISASI Vice President Rob Carter welcomed the Hungarian TSB into ISASI corporate membership. It was also the ideal opportunity for ESASI to hold its formal annual meeting (AGM), led by the President Olivier Ferrante, for which a gratifying number of attendees stayed. For the "serious student," there are extended notes on the AGM on the ESASI website. Broadly, this regional ISASI Society is in stable condition, in organization and finances and with a committee from five separate European states. ESASI is aiming to continue with an annual in-person ESASI seminar, a continuation of shorter online "FocusOn…" sessions, and, hopefully in 2024, a possible hosting of the main ISASI seminar in Lisbon, Portugal.

The postevent reviews have been very good. There seems to be a real taste for this sort of regional event within ISASI and the financial model, where seminar costs are kept low to allow a wide regional attendance. The ESASI committee is extremely grateful to the huge assistance from Beckse and his excellent staff to help make this memorable event on the Danube finally happen. ◆

ASASI Says Aviation Emerging from COVID

Australian Society of Air Safety Investigators (ASASI) President John Guselli observed that Australian aviation is slowly emerging from the global COVID downturn and could return to prepandemic traffic levels during mid-2022. He noted that supply and demand for passenger handling, crewing, airport check-in, and security staffing became more pronounced this spring. ◆

ISASI VP Rob Carter Retires (sort of)

After 37 years at the Air Accidents Investigation Branch in the UK, Rob Carter finally kicked off his wreckage boots and retired on June 10—well, mostly retired as ISASI, European Society of Air Safety Investigators, and Cranfield work continues. In his 37 years at "the branch," Carter saw plenty of drama, including the loss of Pan Am Flight 103 (B-747 at Lockerbie, Scotland) in 1988 and the "Midlands accident" to one of the first B-737-400s at Kegworth a few weeks later. He was involved with a score of RAF Boards of Inquiry, including travel to a BAE Harrier GR7 in northern Iraq (thank you for the tricky recovery, U.S. Army Eagle Flight), an Airbus A300 in the Sumatran jungle in the late 1990s, and 18 months with the investigation of the Concorde near Paris, France, in 2000. Carter expressed thanks to his UK colleagues for their patience and fellowship. He added, "There have been many others (about 140 "fields" in all), and I am deeply grateful for the help and assistance of aviation colleagues throughout the world. And particularly to my children and wife, Candace, who has supported me all the way." ◆

ALPA Plans Safety Forum in Washington, D.C.

The U.S. Air Line Pilots Assocation, an ISASI corporate member, will hold its annual Air Safety Forum at the Omni Shoreham Hotel, Washington, D.C., on September 12–15. For more information, visit safetyforum.alpa.org. ◆

NZSASI Reports Recent Activity

New Zealand Society of Air Safety Investigators (NZASI) Councilor Alister Buckingham said that despite the quiet times that the aviation world has endured for the past two-plus years, interest within NZSASI is being kept alive by a series of webinars organized by Vice President Mike Zaytsoff. These are run as a joint venture with the Honorable Company of Air Pilots (formerly the Guild of Air Pilots and Air Navigators) New Zealand Region.

"The webinars are held monthly on the second Wednesday at 1000 hours NZST (UTC+12). We are always on the lookout for volunteer presenters—one of those already on the list is Robert Sumwalt, recently retired U.S. National Transportation Safety Board chair," said Zaytsoff. Any ISASI members willing to give a presentation (it could be one from a past seminar or a practice run for a future event) should contact Mike at zaytsoffm@gmail.com.

NZSASI membership currently stands at 46, plus three corporate members. "Also in our midst is the current vice president of the Latin American Society, Enriqueta Zambonini, who joined New Zealand's Transport Accident Investigation Commission late in 2021," Buckingham noted. ◆

In Memoriam

Longtime ISASI member Bjarne Prendal of Denmark died on Feb. 3, 2022. He was 80 years old. Bjarne joined the Society in April 1971. ◆

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