Human Error – Aviation Safety's Most Common Accident Theme

Daniel I. Cheney, BS Aerospace Engineering, Safety Program Manager, Aircraft Certification Service, Federal Aviation Administration, USA

Capt. Michael K. Wilson, BS Operations Analysis (USNA '71, USN retired), Aviation Safety Inspector, Flight Standards Services, Federal Aviation Administration, USA

Kimberly A. Campbell, Master of Business Administration, President, QUEST Business Strategies, USA

I. Introduction

THIS paper examines the impact of technological advancements on the successes of aviation since the beginning of the jet era and features the "Achilles Heel" of human error as the predominant safety vulnerability. Despite remarkable successes in certain technologies, it is the human element that now serves as the primary contributor to today's major aviation incidents and accidents, according to the Federal Aviation Administration's (FAA) Human Factors Division.[1]

Underscored is the critical role of safety training and intervention programs that support a zero-error objective. These programs span the lifecycle of the fleet, including: design, certification and manufacturing; training and operations; a best practices maintenance and repair regimen; and quality assurance, inspection, and reporting controls.

Manufacturers, operators, and regulators must be proactive in employing safety management systems (SMS) that have fleet-wide applicability. However, these programs must also be accompanied with the fidelity to identify the "one-off" aircraft that are the forefront of most accidents today. While the SMS programs for fleet and specific aircraft risks vary in design and implementation, both require robust solutions that recognize the aviation industry is often one error away from tragedy.

Accident trend analysis developed by professional industry organizations and specific examples of human error in aviation accidents are highlighted in this paper. Many fitting accident modules can be found through use of the FAA Lessons Learned from Civil Aviation Accidents Library, located at www.faa.gov/lessons_learned. This library was made available to the public in 2009. By emphasizing proactive measures to address human error through comprehensive training and safety protocols, aviation stakeholders, through use of this library, can significantly enhance safety and mitigate risk on the modern jet fleet.

II. Lessons Learned Library Safety Tool

The Lessons Learned from Civil Aviation Accidents Library is a repository of lesson-rich modules that represent deficiencies in technology and human action that have, in many cases, resulted in catastrophic consequences. Developed by the FAA, with indispensable support and cooperation across the aviation industry, the library is available publicly for use by manufacturers, operators, maintenance personnel, aviation management, pilots, universities, training centers, and other key entities. The library contains more than 100 accident modules, developed through use of accident reports from governmental investigative organizations and other reliable sources, that span large transport aircraft, small airplane, and rotorcraft mishaps.

The objective of this library is to equip today's safety practitioners with key knowledge to not only maintain, but to improve aviation safety. It is a valuable learning tool that augments other educational and certification programs and provides safety-relevant information and specific lessons intended to mitigate the risk of similar future accidents. A primary purpose of the library is to ensure aviation safety lessons are not being lost over time and to help the library user understand the evolution of existing safety standards.

The term Lessons Learned refers to the persistent identification and compilation of knowledge-based content that can be used for historical value and instructional purposes. Lessons are carefully crafted to be broadly applicable across manufacturers, operators, and aircraft types. Each lesson is written to be thoroughly understood and subsequently applied throughout industry. These core concepts and their associated take-away messages are garnered from knowledge gained through experience and tragedy and are not simply the main findings and causation described in an accident report. Instead, these tangible lessons stem from the ability to identify, analyze, and employ safety practices and protocols that reduce the risk of reoccurrence. By incorporating these lessons into aviation decision making, we can uncover the evolution of a threat, apply carefully executed interventional techniques, and attempt to ensure that similar, potentially catastrophic errors in aircraft design, operations, and maintenance are not repeated.

The development of these accident modules benefits greatly from contributions made by subject matter experts (SMEs) and insights gathered during groupthink sessions. SMEs, with their deep knowledge and experience in specific engineering, operations, and aviation policy areas, provide valuable perspectives that enrich the library. Groupthink sessions, which involve collaborative brainstorming and reflection among project team members, also serve as a fertile ground for generating the important lessons to be applied to future safety work. Furthermore, all modules are thoroughly vetted by experts within industry to ensure accuracy and completeness.

Today, members of library management regularly present accident investigation training at the FAA academy, through virtual workshops, and to industry forums through demonstration and use of the library. Major airframe manufacturers use the content in their technical staff training. Embry Riddle and other universities throughout the U.S. and in Europe use the library as supplemental curriculum. In Japan, one of the country's largest operators uses the library to augment their structural repair and maintenance training. The library has evolved from one collection of large transport accident modules to three libraries under one domain that include small aircraft and rotorcraft modules. This propagation is anticipated to intensify and uses for the library will continue to grow.

Regardless of aircraft type, it has been determined that most any accident stems from one or more of five common themes. These themes include pre-existing failures, unintended effects, flawed assumptions, organizational lapses, and as featured in this paper, human error.

III. Aviation Safety Successes

As noted in an International Civil Aviation Organization (ICAO) article[2] regarding the future of aviation, in a little over a century, the industry has gone from learning to fly, to learning to fly faster and further, to learning how to fly heavier airplanes, representing more than 100,000 flights worldwide every day. Moreover, the aviation industry has made significant technology progress since the 1950s, leading to more efficient and safer air travel. Profound technological advancements that have improved jet aircraft safety include such innovations as collision avoidance systems, ground proximity warning systems, fuel tank flammability reduction systems, and 16-g seat structural technology, among others.

A. Traffic Alert and Collision Avoidance System (TCAS)

Originating in the 1970s and now mandated for all large transport aircraft, TCAS is designed to increase flightdeck awareness of nearby aircraft, serving as a last line of defense against midair collisions. According to SimuFlight, it is estimated that TCAS has saved the lives of innumerable passengers and crew since its inception and has reduced air traffic delays caused by potential collisions by 25% per year for nearly 30 years.[3] To learn more about TCAS and a midair collision accident that demonstrates the importance of accurately following system procedures, visit this Lessons Learned module.

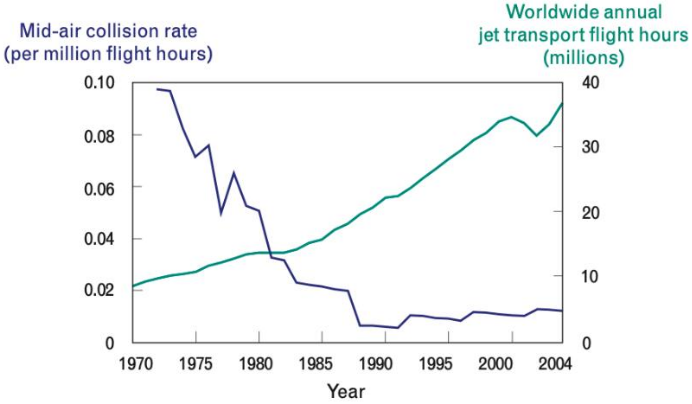

Figure 1: Midair collision rate compared to annual jet transport flight hours

B. Enhanced Ground Proximity Warning System (EGPWS)

Significant strides have been made to reduce the number of controlled flight into terrain (CFIT) accidents through use of EGPWS technology. EGPWSs use present position information from the aircraft's global positioning system, groundspeed information, and a terrain database to allow the EGPWS to "look-ahead," providing terrain awareness, terrain alerts, and warnings to the flight crew. Since 2007, EGPWSs became mandatory equipment in turbine-powered air carrier operations in the U.S. and many other countries. It is estimated that since the introduction of EGPWSs in the late 1990s, CFIT accidents have decreased by approximately 90% among commercial operations, highlighting the significant impact of EGPWS on aviation safety. As shown in this International Air Transport Association (IATA) chart, while CFIT accidents are still a leading cause of fatality accidents, the use of ground proximity warning systems shows a positive and encouraging downward trend.[4] To learn more about the evolution of ground proximity warning systems and an associated large transport accident, see this Lessons Learned module.

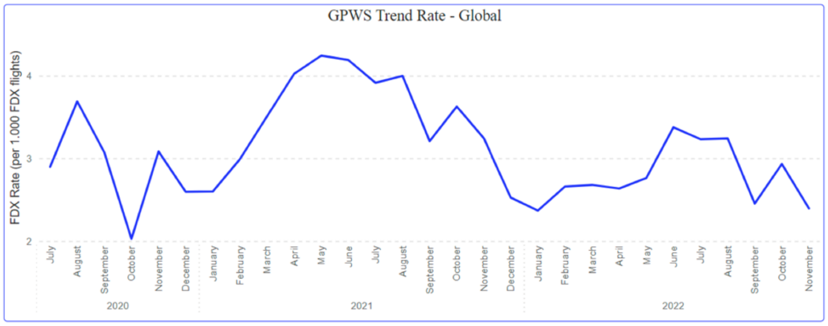

Figure 2: IATA trend data for ground proximity warning systems

C. Flammability Reduction Means (FRM)

Fuel tank flammability reduction means (FRM, U.S.) or flammability reduction systems (FRS, Europe) plays a critical role in enhancing aviation safety by reducing the risk of fuel-related tank explosions. The FAA proposed rulemaking in November 2005 required a means to reduce flammability of certain aircraft. Through analysis, tanks identified as highly flammable required installation of a flammability reduction means. Most of the fuel tank ullage spaces on transport airplanes are vented to atmosphere, and as such, are composed of concentrations of approximately 21% oxygen and 79% nitrogen at sea level. An effective method for reducing the risk of flammability has involved adding nitrogen-enriched air into the ullage space, thereby displacing some of the oxygen.

Several military aviation applications involve this process, referred to as inerting, and result in oxygen content below a level which can sustain combustion. Performance standards for military inerting applications have oxygen concentrations of 9% or less to be explosion proof from combat damage, such as incendiary rounds. Subsequent testing conducted by the FAA established that oxygen concentrations of 12% provided adequate protection against ignition hazards likely to be found on commercial transport airplanes. This recognition provided an opportunity for more cost-effective inerting systems to be developed.

All operators were required to retrofit affected fleets by December 26, 2017, regardless of production date of the aircraft.[5] Since the incorporation of FRM requirements, there have been no further fuel tank explosions for large transport airplanes. To learn more about the inflight explosion of TWA 800, visit this Lessons Learned module.

D. 16g Seats

In October 2009, the FAA mandated that all transport category airplanes used in part 121 passenger carrying operations must meet the 16g seat rule. These passenger seats, able to withstand 16 times the force of gravity, compared with the 9g standard in effect since 1952, serve as another example of technological enhancements in aviation safety. These seats are tested to ensure they provide enhanced occupant protection by maintaining their structural integrity during severe deceleration events or an impact-survivable accident.

An analysis conducted by the FAA on aircraft accidents from 1984-1998 assessed the potential benefit that 16g seats would have on survivability and prevention of serious injuries, assuming that a post-crash fire was not a significant factor. The benefit assessment for the worldwide fleet would have been a reduction of approximately 333 fatalities and 354 serious injuries during this time period.[6] To learn more about an accident that could have benefited from 16g seats, visit this Lessons Learned module.

IV. Human Error – Aviation's Achilles Heel

As written in Homer's *Iliad*, there is a story of Thetis and her son, Achilles, regarding the vulnerabilities of humans. To make Achilles immortal, Thetis dipped Achilles in the River Styx, immersing all but his heel in the protective waters. In later lore, and while in battle, Achilles is mortally wounded in the heel by an arrow, shot by the Trojan prince Paris. To the ancient Greeks, Achilles was known as a model hero who embodied the human condition. As stated by the British Museum, "Despite his greatness, he was still mortal and fated to die."[7]

The Achilles Heel of aviation is the vulnerability of humans to make errors, thereby increasing safety risk. According to Jens Rasmussen, author of *Information Processing and Human-Machine Interaction*, human error is defined as "actions that fail to generate the intended outcomes."[8] These errors are categorized into two groups:

1. Execution failures – The action is appropriate but carried out incorrectly.
2. Planning failures – The action is done correctly but is inappropriate for the situation.

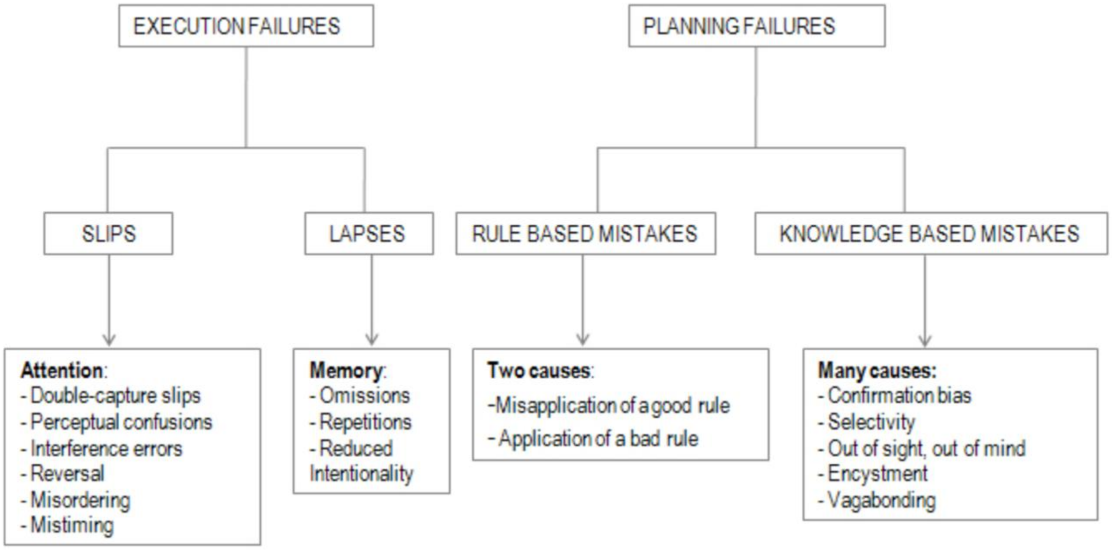

Figure 3: Rasmussen's structure of execution and planning failures

Execution and planning failures can impact aviation safety at both a fleet-wide level or at a one-off aircraft level. SKYbrary, an electronic repository of safety knowledge related to flight operations, air traffic management, and aviation safety in general, applies Rasmussen's human error failure concept to the aviation industry.[9] Results find that human error frequency is as follows:

- 61% of errors are at the skill-based level (slips and lapses)
- 27% of errors are at the rule-based level
- 11% of errors are at the knowledge-based level

However, within the airline industry, humans perform significantly more skill-based tasks than rule-based tasks and more rule-based tasks are performed than knowledge-based tasks. Therefore, any given knowledge-based task is more likely to result in an error. Thus, due to the volume of tasks performed in each category, the number of errors is reversed.

When looking at error detection and correction, the following statistics are at play:

- 70% of skill-based errors are detected and corrected
- 50% of rule-based errors are detected and corrected
- 25% of knowledge-based errors are detected and corrected

These statistical data sets suggest that more errors are derived from knowledge-based sources and that only one-fourth of them are typically detected and corrected.

According to the FAA's Human Factors Division, human error has been identified as a cause in two-thirds to three-fourths of aviation accidents and incidents.[10] This entity states that "FAA human factors personnel seek to understand the many potential contributors to human error, such as inadequate training and procedures, conflicting roles and responsibilities, badly designed equipment, poor communication, fatigue, distraction, and organizational factors."

V. Examples of Human Error-Related Accidents

Within the Lessons Learned Library, approximately sixty percent of the accident modules have human error as a component of mishap causation. Following are select accidents where human error played a significant factor. These accidents are presented in the life cycle stage in which they occurred: design, certification, and manufacturing; operations and training; or maintenance and repair. Each has a correlation to Rasmussen's hierarchy as either an execution or planning failure.

A. Swiss Air Flight 111, MD-11 in Peggy's Cove, Nova Scotia on September 2, 1996

While passing through Canadian airspace, an in-flight fire ensued in the area above the flight deck ceiling, causing loss or malfunction of numerous airplane systems and instruments. The fire propagated throughout the aircraft, which then crashed into the Atlantic Ocean where there were no survivors of the 229 people onboard. Investigative findings determined that the aircraft certification standards for material flammability were inadequate in that they allowed the use of a metalized polyethylene terephthalate-coated insulation material that could be ignited and sustain or propagate fire.

Investigators determined that an arcing event from an electrical wire associated with an inflight entertainment system, installed via an FAA-approved supplemental type certificate, was likely associated with the fire initiation event. Once the fire started, the thermal/acoustic insulation material installed had a propensity to continue burning. As the fire progressed, electronic navigation equipment and communications radios stopped operating, leaving the pilots with no accurate means of establishing their geographic position, navigating, or communicating with air traffic control.

To view more about this accident, visit this Lessons Learned module. Life cycle: Design, certification and manufacturing. *Based on Rasmussen's model, this human error can be attributed to a planning failure that considered the inflight entertainment system to be a non-essential system and therefore limited to examination of system failures.*

B. Turk Hava Flight TK981, DC-10 in Paris, France on March 3, 1974

Approximately ten minutes after takeoff, Flight TK981's radar signature split in two. One target, the aircraft, remained stationary before disappearing from the radarscope. The other target, the cargo door that had separation from the aircraft, turned left to a heading of 280 degrees. The ejection of the aft cargo door was followed by a sudden depressurization of the aircraft, which led to the disruption of the floor structure, impairing the flight controls and making it impossible for the crew to regain control of the aircraft. All 346 passengers and crew were fatally injured.

Investigation of the accident revealed that prior to takeoff, the lower left bulk cargo door was not properly latched and locked. Subsequently, actions were taken by the FAA and industry to address cargo doors, reinforce cabin floors, and improve venting to increase survivability of the aircraft in the event of a major decompression or structural failure.

To view more about this accident, visit this Lessons Learned module. Life cycle: Design, Certification and Manufacturing. *This human error can be attributed to both planning failure, due to cabin door design, and execution failure, based on the expected use/abuse of aircraft equipment.*

C. KLM and Pan American, Boeing 747s in Tenerife, Spain on March 27, 1977

Several aircraft were diverted to an alternate airport due to a bombing at the destination airport. After flights were resumed, two aircraft collided on the runway as the KLM Boeing 747 initiated a takeoff while the Pan Am Boeing 747 was using the runway to “back taxi.”

Investigators found that the fundamental cause of the accident was the KLM captain took off without proper clearance; did not obey the "stand by for takeoff" direction from the tower; did not discontinue the takeoff upon learning that the Pan Am aircraft was still on the runway; and in reply to the KLM flight engineer’s query as to whether the Pan Am aircraft had already left the runway, the KLM captain replied emphatically in the affirmative. Investigators believed that the KLM captain’s decision to takeoff may have been influenced by revised crew duty time limitations that were inflexible and punitive. All 248 passengers and crew onboard KLM were killed. There were also 335 fatalities on the Pan Am flight.

To view more about this accident, visit this Lessons Learned module. Life cycle: Operations and Training. *Using Rasmussen’s model, this human error can be attributed to at least two execution failures that stemmed from flight interruptions/deviations due to an airport closure and a pilot’s decision to takeoff without authority.*

D. Eastern Airlines Flight 401, L-1011 in Miami, Florida on December 29, 1972

While configuring for landing and attempting to lower the landing gear, the flight crew was unable to determine if the nose landing gear (NLG) was fully extended and locked in position. The green indicator light did not show that the gear was locked. Both the main landing gear and the NLG needed to be verified as “down and locked” prior to landing. To allow for confirmation, the captain elected to perform a missed approach to troubleshoot the issue and instructed the first officer to engage the autopilot.

The crew remained focused on the NLG and appeared not to notice the aircraft was in a steady descent. Upon seeing the descent on radar, the approach controller questioned the flight crew as to their status; however, he did not specifically mention altitude in his radio call, which may have prompted the flight crew to check their altimeter. As the airplane was turning toward the airport, the first officer queried about the low altitude as did the pilot. This was followed three seconds later by the sound of initial impact. Of the 163 persons on board 112 were killed in the crash.

Investigators determined that the crash was the result of an inadvertent autopilot disconnection that went unnoticed by the flight crew as they were attempting to resolve an unsafe landing gear indication. It was determined that the uncommanded descent into the Everglades was the result of the flight crew’s failure to monitor the airplane’s flight path and an improper division of duties on the flight deck while troubleshooting an anomalous system indication.

To view more about this accident, visit this Lessons Learned module. Life cycle: Operations and Training. *This human error can be attributed to an execution failure based on the flight crew's focus on gear indicating issues to the total exclusion of operating the airplane.*

E. Japan Airlines Flight 123, Boeing 747 in Gunma Prefecture, Japan on August 12, 1985

Shortly after takeoff, the aircraft experienced an explosive decompression caused by a rupture of the aft pressure bulkhead. The resultant pressure surge into the unpressurized area aft of the pressure bulkhead resulted in extensive damage and loss of the aircraft's auxiliary power unit, rudder, and a large portion of the vertical stabilizer. All four of the hydraulic lines were severed, resulting in complete hydraulic pressure loss, severely degrading controllability. The airplane remained airborne for approximately 30 minutes before crashing in remote, mountainous terrain. Of the 524 passengers and crew onboard, only four survived.

Investigators attributed the explosive decompression to an improperly executed structural repair to the airplane's aft pressure bulkhead that was completed several years prior to the accident. The improper repair led to undetected localized fatigue cracking which undermined the bulkhead's strength and resulted in a catastrophic structural failure of the entire bulkhead.

Following initial repair of the pressure bulkhead, a splice plate was required between the upper and lower halves to recover fastener edge margins that had been found to be inadequate. The splice plate was difficult to install and fit in place. Thus, it was decided that the plate would be split into two pieces, allowing for installation. The division of the splice plate resulted in the tensile loads between the upper and lower bulkhead portions being carried by a single row of fasteners, rather than multiple rows, as intended by the original, one-piece design. The unintended load distribution resulted in a loss of strength in the repaired area, leading to the catastrophic failure of the aft pressure bulkhead.

To view more about this accident, visit this Lessons Learned module. Life cycle: Maintenance and Repair. *This human error can be attributed to an execution failure by implementing a repair solution that did not preserve the original safety features of the airplane.*

F. China Airlines Flight 120, Boeing 737 in Okinawa, Japan on August 20, 2007

Following landing and leading-edge slat retraction, a failed portion of the slat track assembly was pressed through the slat track housing and penetrated the right main fuel tank, causing a fuel leak. The fuel, which leaked from the right-wing tank during taxi and parking, ignited on the hot engine surfaces and brakes, resulting in the aircraft being engulfed in flames. There were 165 passengers and crew on board. While the aircraft was destroyed by fire, everyone was successfully evacuated.

Investigators determined that approximately one month prior to the accident, maintenance had been performed on the No. 5 slat can as part of compliance with a Boeing Service Letter. It was determined that during reassembly of the slat downstop, a single washer was omitted in the reassembly process, leading to the complete destruction of the aircraft by fire. Without the washer, the downstop assembly was eventually able to fall out of the slat track. The downstop assembly fell into the slat can where it was pushed through the wall of the slat can, creating a fuel tank breach and subsequent fire.

To view more about this accident, visit this Lessons Learned module. Life cycle: Maintenance and Repair. *This human error can be attributed to an execution failure where proper implementation of maintenance activities, including disassembly, inspection, and reassembly, was not maintained to preserve safe airplane operation.*

G. Cougar Helicopters, Sikorsky S-92 in St. John's Newfoundland on March 12, 2009

This accident occurred on a helicopter that was transporting workers to an offshore production platform. The aircraft experienced a rapid and complete loss of oil from the transmission's main gearbox. The flight crew declared an emergency and reversed course, attempting to return to its departure airport. The pilot descended the helicopter to approximately 800 feet above sea level and leveled off. Approximately 11 minutes after the rapid loss of oil pressure and during an attempted ditching, the helicopter struck the water at a high rate of descent. One passenger survived with serious injuries and the other 17 occupants were fatally injured.

Investigators determined there were multiple causes associated with this accident. First, following the initial certification loss of lubricant test, instead of redesigning the transmission to provide a 30-minute (run dry) capability, Sikorsky revisited the requirements of Part 29.927(c)(1). With guidance from an Advisory Circular, it was concluded that, except for a potential failure of the oil cooler and its exterior plumbing, all other main gearbox failures leading to a total loss of oil were "extremely remote," or not anticipated to occur to an aircraft during its total life, but which may occur a few times during the total operational life of all aircraft of that type.

Second, the operator determined the end of serviceability of a self-locking nut used in the main gear box to be when the self-locking feature was no longer effective. However, at the time of the accident, Sikorsky required replacing the nuts every time they were removed. Investigators determined the main gearbox oil filter had been replaced a total of 11 times. No records indicated that the nuts securing the filter assembly had ever been replaced since the aircraft was manufactured. The nuts showed remnants of the manufacturer's gray paint that was used on the main gearbox, indicating they were most likely the original nuts.

Third, the captain attempted to fly the aircraft back to shore rather than perform an emergency landing in the water, as directed by the emergency checklist. The helicopter experienced an internal failure to one of the gears in the gearbox, due to lack of lubrication, and the aircraft lost directional control. At this point, an emergency ditching was required but the pilot was flying at an altitude that was too high for proper execution. This resulted in a collision with the water. The aircraft was substantially damaged; therefore, the emergency floats were unable to deploy and the helicopter sank almost immediately.

To view more about this accident, visit this Lessons Learned module. Life cycle: Design, certification and manufacturing; Operations and Training; and Maintenance and Repair. *This human error can be attributed to one planning failure in improper approach to certification. There were also two execution failures for not replacing the nuts following every removal and for not following emergency ditching procedures.*

VI. Intervention Strategies for Human Error in Aviation

It is prudent that industry take systematic and regular action to reduce human error in aviation. The objective should be to set a zero-error tolerance with metrics and improvements for achievement. This must be accomplished through proactive and preventative solutions as well as predictive and reactive means. Procedural deep dives, ongoing on-the-job and recurrent training, implementation of industry best practices, investment in tools and technology, quality inspection protocols, reporting and tracking conventions, and continuous transparent and collaborative communication among stakeholders are crucial elements of a comprehensive safety management system. One such tool that features all listed elements is the Lessons Learned Library.

The library, an award-winning tool recognized by the U.S. Department of Transportation's prestigious annual safety award, is an electronic storeroom for select aircraft accident lessons learned and serves to support aviation safety's culture. The library is a convenience tool; a repository of years of accident analyses and activities conducted by a variety of experts and organizations that is summarized and enhanced to make it easy for the reader to find, use, and retain safety-related information for learning and comparative purposes.

The FAA created this public website for use by industry, regulators, and academia. More than sixty of the library's aircraft accident modules (nearly 60% of total) are linked to one or more human error factors. These modules represent a wealth of training opportunities for today's workforce, from the limited-experienced new hires to the well-experienced veterans. This invaluable resource should be mined to create training opportunities that could ensure greater safety for aviation workforces worldwide. The inclusion of more than 50 years of select jet era accidents with their lessons learned can be converted into a wealth of training material. Without learning from the past, regulators and industry are certain to see these accidents repeated.

VII. Conclusion

Like the mortal vulnerability of Achilles, human error serves as the greatest risk to aviation safety. Human error can be attributed to execution failures and planning failures. Focused action on human error intervention and prevention are imperative to industry and the flying public. Aviation stakeholders must adopt and implement interventions that are based on zero-accident tolerance.

The FAA's Lessons Learned Library is a robust training tool that uses past accidents as the basis for future avoidance. This tool can be instrumental in the formation of industry teaching programs that support engineers, pilots, maintenance personnel, policy developers, and more. This library is a dynamic repository that evolves through a blend of analyses and the collective wisdom of its team members and experts. It is a testament to the FAA's commitment to safety management through continuous improvement and knowledge sharing. This valuable resource of actionable lessons garnered from aviation's most tragic circumstances can ensure human error or any threats are less likely to reoccur.

References

[1]"The Role of Human Factors in the FAA." www.hf.faa.gov/role.aspx, accessed on 19 Jul 2024.

[2]"Future of Aviation," International Civil Aviation Organization (ICAO), 2013, https://www.icao.int/Meetings/FutureOfAviation/Pages/default.aspx, accessed on 25 Jul 2024.

[3]"TCAS in Aviation – Understanding the What and Why (2002)," *SimuFlight*, 10 Mar 2022, https://simuflight.co.za/tcas-in-aviation/.

[4]"IATA Annual Safety Report – Recommendation for Accident Prevention in Aviation," 2002, www.iata.org/contentassets/95e933e1ad794068812f073cf883cb08/recommendations-for-accident-prevention-in-aviation.pdf.

[5]"Compliance Plans for Retrofit of Flammability Reduction Means to Transport Airplanes Fuel Tanks," Federal Aviation Administration, Information for Operators, 10 Mar 2014.

[6]Cherry, Ray, et al., "Benefit Analysis of Aircraft 16-g Dynamic Seats," DOT/FAA/AR-00/13, U.S. Department of Transportation FAA, April 2000, www.fire.tc.faa.gov/pdf/00-13.pdf.

[7] "Who was Achilles?" The British Museum, 15 Oct 2019, www.britishmuseum.org/blog/who-was-achilles.

[8] Rasmusssen, Jens, *Information Processing and Human-Machine Intervention – An Approach to Cognitive Engineering*, Elsevier Science Ltd., 1 Jan 1986, first edition.

[9] "Human Error Types," SKYbrary, https://skybrary.aero/articles/human-error-types, accessed on 23 Jul 2024.

[10] "The Role of Human Factors in the FAA." www.hf.faa.gov/role.aspx, accessed on 19 Jul 2024.