FORUM

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Although not required by regulation, a lightweight flight recording system on board this Mitsubishi aircraft aided investigators to sequence events leading to the 2016 collision with terrain near Îles-de-la-Madeleine Airport in Québec, Canada (see page 4).

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AIR SAFETY INVESTIGATORS
INCORPORATED AUGUST 31, 1964

TOBY CARROLL RETIRES

Putting my thoughts and feelings into words about a lifelong air safety advocate and ISASI activist with whom I have worked closely for my entire accident investigation career is difficult. And in this case, it is about someone who has never been at a loss for words.

So I will just say it. Toby Carroll has recently retired as president of the U.S. National Society and as the U.S. councilor—positions he has held since 2009. Prior to that, he was vice president and treasurer of the Dallas-Ft. Worth Chapter. He served in those offices with commitment and zeal on behalf of the Society and aviation safety throughout the world.

Toby's military service in the Army included a tour as a fixed-wing pilot in Vietnam and then assignment to the Army Aviation School as a committee chief/instructor. Following active duty, Toby served in the Army Reserve and National Guard as a company commander and operations officer. Toby always claims that he was an accidental air safety investigator. He was "volunteered" to participate in an accident investigation that he found interesting and challenging. He took the path less traveled, and the rest is aviation safety history. His final assignment was as the 50th brigade safety officer where he established the brigade's aviation and ground safety programs. During his military career, Toby received numerous decorations, including the Distinguished Flying Cross, the Air Medal with 14 oak clusters, the Bronze Star, and an Army Commendation Medal with cluster.

Toby Carroll, U.S. National Society president, left, receives the 2016 Jerome F. Lederer Award from ISASI President Frank Del Gandio.

Upon completing his active duty, Toby worked for a company that investigated aviation accidents for various manufacturers and subsequently for the U.S. National Transportation Safety Board at its New York field office. My first encounter with Toby was during this time in the late 1970s when we investigated a general aviation accident together. Toby joined ISASI in 1982. And in all the years since then, he's missed only two ISASI annual seminars. My wife and I became good friends with Toby and his wife, Kathy, and always looked forward to the council meetings and seminars to spend time together.

In 1985, Toby became the manager and later the director of flight safety for Continental Airlines, where he was instrumental in establishing numerous safety programs—many of which are now industry-standard practices. He was a strong advocate for proactive safety programs and chaired numerous aviation industry committees.

I was reacquainted with Toby on a Continental Airline accident investigation after I transferred to Washington, D.C., and was on the FAA go-team in 1980. I was an FAA investigator, and he was with the Continental team that participated in NTSB investigations. He also served as a technical advisor to the NTSB accredited representatives on International Civil Aviation Organization Annex 13 investigations. I quickly learned that Toby was the "go-to" person if I needed information about airlines, especially their safety practices and procedures. During his active investigation career, Toby participated or was in charge of more than 400 accident and incident investigations. And he was always ready to share his experience and expertise—to anyone who would listen. I learned a lot about safety investigation techniques and procedures from him—many things you might not understand as well from books or training classes. Sometimes my FAA colleagues would ask where I got so much good airline information. I just said my source was reliable.

ISASI recognized Toby's lifetime contributions to aviation safety and to ISASI with the Jerome F. Lederer Award in 2016. He has been a positive force for air safety throughout his career, and his penchant for passing on his expertise to others—including me—will ensure that his contributions will continue for generations to come. All of us involved in ensuring air safety owe Toby a great debt and wish him well in his retirement. ◆

Frank Del Gandio
ISASI President

(Adapted with permission from the authors' technical paper Research-Based Insights Through Accident Investigations: The Importance of Lightweight Flight Recording Systems for Accident Investigations *presented during ISASI 2019, Sept. 3–5, 2019, in The Hague, the Netherlands. The theme for ISASI 2019 was "Future Safety: Has the Past Become Irrelevant?" The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)*

RESEARCH-BASED INSIGHTS THROUGH ACCIDENT INVESTIGATIONS:

THE IMPORTANCE OF LIGHTWEIGHT FLIGHT RECORDING SYSTEMS

By Beverley Harvey, Senior Investigator, International Operations and Major Investigations, Air Transportation Safety Board of Canada; Bruce Mullen, Regional Senior Investigator, Operations, Air Investigations-Atlantic, Transportation Safety Board of Canada; and Christina M. Rudin-Brown, Manager, Human Factors and Macro Analysis Division, Transportation Safety Board of Canada

The question for ISASI 2019's participants is whether the past has become irrelevant. Certainly, some issues have become irrelevant; investigators have come a long way with access to more modern investigation techniques because of knowledge gleaned from the past. With modern technology, investigators can rely solidly on rapid communications and assistance from first responders, coroners, and manufacturers whose expertise is instantly available for all phases of the investigation. For example, technology regarding photography has improved so much that, instead of having to wait for good weather and a helicopter to film the wreckage site, excellent drone photography is instantly available. This enables investigators to concentrate on their job of combing through the wreckage site, photographing components, interviewing witnesses, and then taking the accident from the outdoors to their computers.

However, there is one challenge in Canada that still needs to be solved. This challenge stems from the absence of regulations for the implementation of lightweight flight recording systems for privately operated aircraft (the private operation of any aircraft type listed in Section 604.3 of the Canadian Aviation Regulations [CARS] and engaged in noncommercial flight operations must abide by specific regulations set out in CARS Subpart 604) and other commercial aircraft not currently required to carry crash-protected flight recorders.

Advanced technology in this field has resulted in recorders that are very sophisticated, light in weight, and much less costly than earlier models. In the distant past, recorders on large commercial aircraft were not regarded as being essential; but once the benefits were demonstrated in accident investigations, recorders became mandatory.

So it is today—the emergence of lightweight flight recording systems is starting to show the benefits in accident investigations and normal day-to-day data collection. Canada still has sectors of aviation in which recorders are not mandatory for some commercial operators and privately operated aircraft. Our challenge is to demonstrate how effective lightweight flight recording systems are in accident investigations and continue to recommend that the government address this issue in a timely fashion.

This paper will discuss two high-profile accidents investigated by the Transportation Safety Board (TSB) of Canada. Both involved privately operated aircraft, and these accidents occurred in 2016 within months of each other. There are similarities between the two; however, the findings are quite different because one aircraft had a lightweight flight recording system on board and the other aircraft did not.

The first accident that this paper will examine is from the TSB's aviation investigation report A16A0032: Collision with terrain/Mitsubishi MU-2B-60, N246W/Îles-de-la-Madeleine Airport in Québec, Canada, March 29, 2016.

TSB report summary

On March 29, 2016, a privately operated Mitsubishi MU-2B-60 aircraft (registration N246W, serial number 1552S.A.) departed Montréal/Saint-Hubert Airport in Québec on an instrument flight rules flight to Îles-de-la-Madeleine Airport in Québec. The pilot, a passenger-pi-

Beverly Harvey from the Transportation Safety Board of Canada at the accident scene.

lot, and five passengers were on board. During the final approach to Runway 07, when the aircraft was 1.4 nautical miles west southwest of the airport, it deviated south of the approach path. At approximately 1230 Atlantic daylight time, aircraft control was lost, resulting in the aircraft striking the ground in a near-level attitude. The aircraft was destroyed, and all occupants were fatally injured. There was no postimpact fire.

A lightweight flight recording system was on board the occurrence aircraft, although it was not required by regulation. This device was a cell phone that had GPS, voice recording, and accelerometer capabilities; it was attached to the aircraft's radio. Although it was not a crash-survivable recorder, TSB investigators recovered the recorder from the wreckage, and the TSB engineering laboratory was able to extract and analyze its data. The resulting information was critical to understanding the sequence of events that led to the aircraft's departure from controlled flight; without recorders, crucial information to understand these events would not have been available.

Data retrieval and analysis

The investigation successfully recovered data from the terrain awareness and warning system and the Wi-Flight recording device. These data were used to reconstruct the flight profile during all stages of flight, enhancing the investigators' ability to understand and analyze the final moments before impact. The audio retrieved from the Wi-Flight was complete and instrumental to the understanding of the events leading to the accident.

Although not required by regulation, the installation and use of a lightweight flight recording system during the occurrence flight, as well as the successful retrieval of its data during the investigation, permitted a greater understanding of this accident.

The final report found that the cause of the aircraft's upset and subsequent impact was due to a loss of control that occurred when the pilot rapidly added full power at a low airspeed while at a low altitude, causing a power-induced upset. This resulted in the aircraft rolling sharply to the right and descending rapidly. It was the analysis of the recordings that allowed the determination of the rapid throttle advance by the pilot.

The second accident that this paper will examine is from the TSB's aviation investigation report A16P0186: Loss of control and collision with terrain/Cessna Citation 500, C-GTNG/Kelowna Airport, British Columbia, Canada, Oct. 13, 2016.

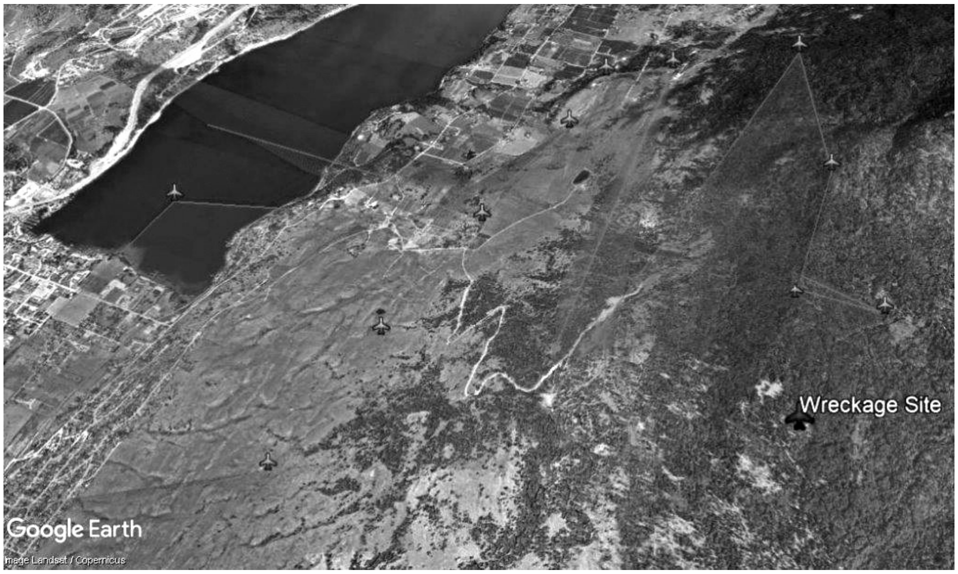
TSB report summary

On Oct. 13, 2016, a privately operated Cessna Citation 500 (registration C-GTNG, serial number 500-0169) departed Kelowna Airport (CYLW) in British Columbia on an instrument flight rules night flight to Calgary/Springbank Airport (CYBW), Alberta, Canada. The

Beverley Harvey

Bruce Mullen

Christina M. Rudin-Brown



Multilateration surveillance data of the accident.

pilot and three passengers were on board. Shortly after departure, at about 2135 Pacific daylight time, the aircraft made a tight right turn as it was climbing through 8,600 feet above sea level and then entered a steep descending turn to the right until it struck the ground. All of the occupants were fatally injured. Impact forces and a postimpact fire destroyed the aircraft.

The high-energy impact resulted in a crater approximately two feet deep. Fragmented aircraft debris was projected into trees and scattered around a small area. The postimpact fire destroyed most of the aircraft structure.

Investigators were able to determine that the engines were producing power at the time of impact and that there was no in-flight breakup or separation of the wings. Weather conditions at the time of the accident did not appear to be conducive to significant icing. There were no difficulties with radio communications, and none of the communications between the pilot and air traffic control revealed any sense of urgency or any anomalies with the aircraft. There was no evidence that pilot fatigue was a factor.

In contrast to the first accident, the information normally contained in flight data recording systems was not available to this investigation. The aircraft was not equipped with a flight data recorder (FDR), a cockpit voice recorder (CVR), or any other lightweight flight recording system, nor were any required by regulation. Consequently, it was a challenge to establish a detailed sequence of actions in the cockpit, and, as a result, it could not be determined if there was an abnormal event before the aircraft's rapid descent.

Although there were no recordings on board, the TSB engineering laboratory was able to work with the raw radar data that was available from two radar sites in the vicinity of the accident site.

The goal was to determine the aircraft's flight path (ground track and altitude) as well as to calculate vertical velocity, ground speed, and deviation from the published standard instrument departure routing. This information was then used to document the flight, synchronized in time with the air traffic control recording.

This raw radar data consisted of multilateration (MLAT) surveillance data provided by NAV CANADA. The MLAT data were inaccurate for the takeoff because there was significant scatter in the radar targets. For the latter part of the flight, when the aircraft transitioned into a steep descending turn, accurate MLAT data were also not available.

The climbout segment of the ground track was generally smooth and consistent. Several radar targets were obviously false targets (off track) in the MLAT data. Since the aircraft was only equipped with a single bottom-mounted transponder antenna, depending on the aircraft's position and attitude, the antenna may have been shielded from a significant number of the radar sensors. Position inaccuracies could have occurred because some of the blocked sensors may have detected reflections off nearby terrain, rather than transponder replies directly from the aircraft.

What exactly happened during the final part of the flight is unknown because there was a lack of data to be able to determine the precise tracking of the aircraft during the steep descending turn. However, it is likely that there was a tightening turn to the right given the trend suggested in the data.

Investigators were unable to identify and fully understand the underlying causal and contributory factors. The investigation's sole finding as to cause and contributing factors was that the aircraft departed controlled flight, for reasons that could not be determined, and collided with terrain.

The relevant finding in the TSB accident report as to risk was that, if flight data, voice, and video recordings are not available to an investigation, the identification and communication of safety deficiencies to advance transportation safety may be precluded.

For several decades now, FDRs and CVRs have been conceived, designed, and installed in order to record flight and cockpit data for accident investigation purposes. FDRs record a number of aircraft parameters—such as altitude, airspeed, and heading—many times per second. CVRs record radio transmissions and ambient cockpit sounds, including pilot voices, alarms, and engine noises. Image/video recorders capture and provide video of the crew immediately before, during, and after an event.

Currently, FDRs and CVRs are consid-

Although not required by regulation, a cell phone that had GPS, voice recording, and accelerometer capabilities was attached to the Mitsubishi aircraft's radio.

ered the most comprehensive methods of capturing large amounts of flight data for accident investigations. Investigations can also obtain data from other sources, such as iPads, tablets, smartphones, GPS units, engine monitors, and other nonvolatile memory sources that are not crash-protected. Investigators who have access to data from FDRs and CVRs, as well as from these other types of lightweight recording systems, are more likely to identify safety deficiencies than investigations who do not benefit from FDR and CVR data.

In 2016, the International Civil Aviation Organization (ICAO) amended Annex 6 of its standards and recommended practices to recommend that certain categories of aircraft and helicopters flown by commercial operators carry lightweight flight recorders. The European Organization for Civil Aviation Equipment (EUROCAE) established the minimum operational performance specification for lightweight flight recording systems, ED-155, and ICAO references this document. As well, ICAO Annex 6 outlines the minimum specifications for such systems. To comply with recent amendments to ICAO Annex 6 and to address 12 safety recommendations issued by seven different investigation bodies in Europe, the European Union Aviation Safety Agency (EASA) published a notice of proposed amendment (NPA) in 2017, under which new regulations would prescribe lightweight flight recorders for some categories of commercially operated aircraft and helicopters.

In Canada, FDR and CVR regulations are currently specified in Section 605.33 of the CARs, Flight Data Recorder and Cockpit Voice Recorder. Under this provision, the requirements for CVR and FDR equipment in aircraft are based primarily on the number and type of engines, number of passenger seats, and type of operation. Given the design characteristics and configurations, many aircraft flown by private operators, including both aircraft that were involved in the accidents discussed in this paper, are not required by regulation to be equipped with either an FDR or a CVR.

EUROCAE's minimum operational performance specification for lightweight flight recording systems defines the minimum specifications for lightweight flight data recording systems; Transport Canada (TC) does not currently have any regulatory requirements or specifications.

To provide an accessible and feasible means of recording valuable flight data information, regardless of the type of aircraft and operation flown, several lightweight flight recording systems currently manufactured can record combined cockpit image, cockpit audio, aircraft parametric data, and/or datalink messages. Although there are currently no regulations in Canada requiring any aircraft to be equipped with lightweight flight recording systems, these devices provide a potential cost-effective alternative for some sectors of the civil aviation industry.

In 2013, following its investigation into a fatal in-flight breakup occurrence in March 2011 northeast of Mayo, Yukon, Canada, the TSB concluded there was a compelling case for implementing lightweight flight recording systems for all commercial operators. The TSB recommended that the TC work with industry to remove obstacles to and develop recommended practices for the implementation of flight data monitoring (FDM) and the installation of lightweight flight recording systems by commercial operators not currently required to carry these systems (TSB Recommendation A13-01).

The TC has acknowledged that FDM programs would enhance safety and has taken the following actions to address the safety deficiency identified in Recommendation A13-01:

- In 2013, after conducting a risk assessment to evaluate alternative approaches to FDM, the TC informed the TSB that it supported Recommendation A13-01. In 2015, the TC informed the TSB that it intended to revisit this risk assessment.
- In 2013, the TC informed the TSB that it would develop an advisory circular outlining recommended practices for FDM programs.
- In 2013, the TC informed the TSB that it would incorporate its analysis and review of Recommendation A13-01 into its planned assessment for FDRs and CVRs, which was scheduled to begin in 2014–2015.
- In 2014, the TC informed the TSB that it would consider adding FDM principles in future regulatory initiatives and amendments.
- In 2015, the TC informed the TSB that it would prepare an issue paper on the use of FDM, providing information on FDM, including its benefits, costs, and challenges. Due to other ministerial commitments, the TC has not initiated its work for any of these undertakings.

In February 2018, the TC conducted a focus group with industry stakeholders to evaluate the challenges and benefits of installing lightweight flight recording systems on aircraft that are not currently required to carry these systems. However, until the focus group reaches conclusions concerning these challenges and benefits in small aircraft, and the TC provides the TSB with its plan of action following those conclusions, it is unclear when or how the safety deficiency identified in Recommendation A13-01 will be addressed.

Although Recommendation A13-01 targeted commercial operators, the contrast in available evidence demonstrated between the Îles-de-la-Madeleine and the Kelowna aircraft accidents discussed in this paper highlights the value of installing lightweight flight recording systems on privately operated aircraft as well. Investigators are at a disadvantage in determining the causes of an occurrence when no flight data are available, regardless of whether the investigation involves an aircraft operated commercially or a business aircraft operated privately.

From past TSB investigation reports, it has been demonstrated that investigators have been unable to determine the reasons for an accident because of the lack of onboard recording devices. The benefits of recorded flight data in aircraft accident investigations are well known and documented. Because of the compelling evidence that the lack of recording devices on board commercial aircraft and private aircraft continues to impede the TSB's ability to advance transportation safety, the TSB board recommended that the Department of Transport require the mandatory installation of lightweight flight recording systems by commercial operators and private operators not currently required to carry these systems (TSB Recommendation A18-01 that replaced TSB Recommendation A13-01).

In the first accident discussed in this paper at Îles-de-la-Madeleine Airport, there was a lightweight flight recording system on board although it was not required by regulation. By recovering the recorder and extracting its data for analysis, investigators were able to have an accurate understanding of the sequence of events that led to the aircraft's departure from controlled flight. Had a recording system not been on board, crucial information to understand the circumstances and events leading up to this occurrence would not have been available to the investigation.

In contrast, the information normally recorded by FDR or CVR systems was not available for the second accident discussed in this paper. Investigators could not positively determine why the aircraft departed controlled flight and collided with terrain. Because this aircraft was not equipped with any type of lightweight flight recording system, investigators were precluded from fully identifying and understanding the sequence of events and the accident's underlying causes and contributing factors.

When investigators have access to recorded data on board an aircraft, they can quickly figure out what happened, and then it is possible to spend precious time and resources concentrating on the issues as to why the accident happened. Otherwise, time is needlessly spent testing and discounting hypotheses, and other issues that are deemed irrelevant to the investigation. ◆

The Mitsubishi MU-28-60 suffered a loss of control and collision into terrain while on approach to Îles-de-la-Madeleine Airport, Québec, resulting in the loss of all seven people on board.

The Cessna Citation 500 also suffered loss of control and collision with terrain while on departure from Kelowna Airport, British Columbia, with the loss of all four people on board.

Aviation Safety of Remotely Piloted Aircraft Systems in China

By Lin Yang, Air Safety Investigator and Senior Engineer, China Academy of Civil Aviation Science and Technology, Civil Aviation of China; and China Postal Airlines

(Adapted with permission from the author's technical paper Review of Aviation Safety Regulation and Practices of Remotely Piloted Aircraft Systems [RPAS] in China *presented during ISASI 2019, Sept. 3–5, 2019, in The Hague, the Netherlands. The theme for ISASI 2019 was "Future Safety: Has the Past Become Irrelevant?" The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)*

Lin Yang

Development of RPAS in China

The industrial chain related to remotely piloted aircraft systems (RPAS) has developed rapidly.

At the end of 2016, the State Council issued the National Emerging Industry Development Plan for Five-Years (2016–2020) that promotes the development of RPAS that can be used in multiple sectors to meet market demand. National policies and broad prospects will enable the RPAS industry to enter a robust development phase. RPAS has been applied in various industries such as agriculture, forestry, mining, infrastructure assessment, power line and pipeline inspection and monitoring, aerial mapping, firefighting and disaster relief, environmental protection, meteorological observation, highway management, postal express delivery, film and television production, and aerial photography, etc.

According to the forecast for 2017–2021, the market scale of industry-level RPAS will grow at a rapid rate of 30% per year, and there is a trend to replace the existing manned aircraft in many fields such as general aviation and freight aviation. RPAS for agriculture will be popularized nationwide in 2019, and in 2022, agriculture and recreational aerial photography will be gaining popularity.

In February 2017, the Civil Aviation Administration of China (CAAC) issued information bulletin General and Small Transportation Operation Overview 2016 (IB-FS-2017-011). As of Dec. 31, 2016, the number of RPAS with various certificates managed by industry associations in China totaled 8,113, a significant increase compared to 1,898 in 2015 and 244 in 2014. In March 2017, CAAC issued the Annual Report on the Development of Civil Aviation Pilots (2016). As of Dec. 31, 2016, the total number of civil RPAS pilot licenses was 10,255, an increase of nearly four times compared to the number of certificates issued in 2015. These certificates were mainly distributed to manufactures, research and development enterprises, and universities. There are 158 qualified RPAS pilot training institutions, nearly double the number in 2015. Today, most drone operators in China are individuals under the age of 40.

In February 2018, CAAC issued information bulletin General and Small Transportation Operation Overview 2017 (IB-FS-2018-12) and Annual Report on the Development of Civil Aviation Pilots (2017). As of Dec. 31, 2017, the number of certificates held by various types of RPAS pilots managed by industry associations had increased to 24,407, including 2,121 fixed-wing, 1,343 helicopters, 20,833 multirotors, 9 airships, and 101 vertical takeoff and landing fixed-wing, which are mainly distributed to companies that manufacture drones, research and development enterprises, and universities. A total of 199 pilot training institutions have training qualifications.

In February 2019, CAAC issued information bulletin General and Small Transportation Operation Overview 2018 (IB-FS-2019-15) and Annual Report on the Development of Civil Aviation Pilots (2018). As of Dec. 31, 2018, the number of registered civil RPAS had increased to more than 180,000, with 44,573 pilot licenses for various types of RPAS, including 3,131 fixed-wing, 1,624 helicopters, 39,278 multirotor wings, 11 airships, and 529 vertical takeoff and landing fixed-wing. There are eight approved cloud system providers for RPAS, six of which are connected to the cloud exchange system—U-Cloud, U-Care, BD-Cloud, 5U Cloud, FindDrone, and Xcloud—with a total of 988,625 flight hours in 2018.

According to the report from RPAS Real-Name Registration System, as of Jan. 24, 2019, about 295,000 RPAS had been registered, including 25,000 with a maximum takeoff mass (MTOM) of more than 25 kilograms to 150 kilograms, 571 RPAS with a MTOM of more than 150 kilograms, and 49 RPAS with a MTOM of more than 650 kilograms. There are 268,000 RPAS owners, 3,720 types of RPAS, and 1,239 manufacturers and agents registered.

Violations Cases of RPAS/RPAS Incidents

Meanwhile, taking advantage of regulations and new technologies to supervise RPAS attracts more attention. In fact, the safety risks of RPAS are not only a problem for China, but also for the world. In recent years, there have been multiple incidents of flight delays and airport closures caused by the illegal invasion by RPAS. The illegal operation of low, slow, and small aircraft such as RPAS has become a significant concern affecting flight safety and even national and social security. As the usage of RPAS becomes more prevalent so, too, do the conflicts between RPAS operators and airliners.

On the evening of May 28, 2016, an RPAS appeared in the airspace of Chengdu Shuangliu International Airport's eastern runway, resulting in the runway closure for just more than one hour and 55 flight delays. This was the first time that an RPAS had affected the flights at Chengdu Airport, the fourth largest aviation hub in mainland China.

On April 17, 2017, in the airspace near Chengdu Airport, an RPAS interfered with flights again. The control center of the southwest Air Traffic Management Bureau (ATMB) immediately implemented the emergency plan and diverted 11 flights to Chongqing Jiangbei International Airport to ensure flight safety and ground safety. In April 2017, eight consecutive RPAS disturbances occurred in the Chengdu region, causing 138 flights to return and divert.

On the evening of Feb. 6, 2019, several RPAS disturbances occurred over Xi'an City, causing flight disruptions for nearly five hours. At 1734, the pilot on a flight at about 1,600 meters above the ground was passing over Xi'an enroute to Xi'an Xianyang Interntional Airport when he reported to the air traffic controller that an RPAS was spotted within 100 to 200 meters directly above him. In the past two years, CAAC has issued relevant measures for handling RPAS due to numerous disturbances. Upon receipt of the report, the air traffic controller immediately implemented the emergency response plan and set up a temporary avoidance airspace. This airspace covered a horizontal radius of six kilometers and a vertical radius of 600 meters from the crew. The controller then directed the aircraft to fly around the airspace, reported the situation to subsequent flights, and continuously observed the dynamics of the RPAS.

About 10 minutes later, another flight crew reported an RPAS near the east gate of Xi'an City. Due to poor visibility and fast flight speed, the crew could not determine the specific height and type of the RPAS. The air traffic controller immediately set up a temporary avoidance airspace at the reported location in accordance with the procedures. At 1821, the flight crew of an aircraft 2,400 meters above the ground in the southwest part of Xi'an City reported that a black, barrel-shaped RPAS was flying at a horizontal distance of one kilometer from and at a vertical height of 200 meters from the crew, which is very dangerous. Due to continuous reports from aircrews and the influence of the RPAS's flight height on the safety of normal flights, the on-duty leader of the northwest ATMB immediately decided to change the flight procedures of arriving flights and relayed that all flights should avoid flying over Xi'an City.

In the next few hours, the air traffic controller instructed all arriving flights to avoid the airspace according to the emergency plan. At about 2200, the controller gradually directed aircraft to resume the normal flight procedures and informed the crews to remain alert for RPAS. The airspace restriction was lifted at 2215 once no additional RPAS sightings were reported. Due to the timely and proper execution of emergency protocols, there were no significant disturbances to normal flight operations.

An RPAS fuselage is mostly made of aluminum and carbon fiber composite materials. After colliding with a manned aircraft, the degree of damage is worse than that of a bird strike. However, due to the limited power and endurance, this type of RPAS has an active radius of five to 10 kilometers and a maximum relative height of climb no more than one kilometer. Therefore, the impact on civil aviation is mainly concentrated on the takeoff, approach, and landing phases, and conflicts with aircraft mostly occur in airport terminals. While there have not been any collisions between flights and RPAS in China thus far, there have been many incidents in which RPAS have intruded airport runways and approach routes, resulting in serious incidents and posing great threats to safety.

Evolution of Regulations

In 2009, CAAC issued the airworthiness management document Interim Provisions Related to the Administration of RPAS (ALD2009022), which regulated the registration and administration of civil RPAS with reference to civil aircraft management measures. Before an RPAS can fly, the RPAS operator must receive temporary registration approval from CAAC and display the registration on the body of the RPAS according to the aviation procedure Regulation on the Nationality Registration of Civil Aircraft of P.R. China (AP-45-AA-2008-01R3). Prior to each flight, the operator should apply for a special flight permit from CAAC Regional Administrations according to the aviation procedure Issuing and Managing Airworthiness Certificates for Civil Aviation Products and Parts (AP-21-05R1). RPAS with temporary registration certificates and special flight permits shall operate in accordance with the rules of air traffic management, operational management, and radio management to ensure safety.

CAAC continued to carry out the administration of RPAS and successively published the Advisory Circular Interim Operating Provisions for Low-Level Operation of Light and Small Unmanned Aircraft Systems (AC-91-FS-2015-31, issued on Dec. 29, 2015) and management document Measures for Air Traffic Management of Civil RPAS (MD-TM-2016-004, issued on Sept. 21, 2016).

In response to illegal RPAS flights that affect the operation of civil aviation in many airports across the country, major airports have actively carried out special rectification activities for airborne objects such as RPAS in accordance with the Notice on Further Strengthening the Management of Airborne Objects such as RPAS in the airport clear zone. This includes drafting work plans for RPAS and other airborne objects in the airport clear zone and becoming more vigilant of such zones. The no-fly zone of the airport has been determined through negotiation with the air traffic control station, and a no-fly zone is an area bounded by 10 kilometers on both sides of the centerline of the runway and 20 kilometers outside both ends of the runway. Major airports coordinate with relevant departments to carry out preventive measures, establish a long-term management mechanism for the joint defense of airports, clarify the stakeholders for the management of RPAS and other airborne objects in the airport clear zone, and publish the map of the airport no-fly zone to the public.

CAAC has implemented the aviation procedure Regulations on Real-Name Registration of RPAS (AP-45-AA-2017-03, issued on May 16, 2017), which has gradually strengthened the management of RPAS pilots.

On July 19, 2017, CAAC required that flight crews report potential RPAS conflicts. After spotting an RPAS, flightcrew members should immediately report the key information such as the time and location of encounter, flight phase, relative position (left, right, or center), relative aircraft altitude (above, below, or same altitude), shape (multirotor, fixed-wing, helicoper, or other), and color of RPAS to the air traffic controller if they believe that it poses a threat to flight safety. Within 24 hours, the flight crew should fill out the Drone Encounter Report and submit it to the airline's Operation Control Department for review. These reports play an important role in mitigating the risk of RPAS interfering with the operation of flights, promote the smooth flow of information related to RPAS in all aspects of monitoring such as RPAS location data gathering, improve the standardization of conflict data reporting of RPAS, and optimize the decision-making process of regulatory authorities in taking timely risk mitigation measures.

In December 2017, CAAC began to implement the recommended standards of RPAS Fence and RPAS Cloud System Interface Data Specification to further improve the legal and regulatory system.

In 2018, CAAC successively issued the information bulletin Safe Flight Test Report for Low-Level Networked RPAS (IB-FS-2018-011, issued on Feb. 6, 2018), management document Interim Administrative Measures for Commercial Flight Activities of Civil RPAS (MD-TR-2018-01, issued on March 21, 2018), and Advisory Circular Regulations for Civil RPAS Pilot (AC-61-FS-2018-20R2, issued on Aug. 31, 2018).

In 2019, three Advisory Circulars (drafts for comments) Operating Provisions for Low-Level Operation of Light and Small Unmanned Aircraft Systems (AC-91-FS-2019-31R1, amendment to AC-91-FS-2015-31), Regulations on Submission and Management of Flight Data of Light and Small Civil RPAS (AC-93-TM-2019-01), and Regulations for Civil RPAS Pilot (AC-61-FS-2019-20R3, issued on Aug. 31, 2019, amendment to AC-61-FS-2018-20R2) were issued. Advisory Circular Interim Regulations for Specific Category of RPAS Operation (AC-92-2019-01, issued on Feb. 1, 2019), Guidance on Airworthiness Approval of RPAS Based on Operational Risk (issued on Jan. 25, 2019), and recommended standard of Data Specifications of Unmanned Aircraft Cloud System (draft for comments, issued in June 2019) were also issued. The management protocols of RPAS training institutions personnel are also being developed.

Meanwhile, the draft of China Civil Aviation Regulation Part 92 Safety Management Rules for RPAS (CCAR-92) is being developed to further improve and integrate the relevant regulations for the management of RPAS within the civil aviation area. CCAR-92 will include the registration and certificate of civil RPAS, personnel management, operational management, airspace management, and other aspects.

On the state level, according to the legislative framework of the State Council and the Military Commission, the State Council and the Office of the Air Traffic Control Committee of the Military Commission published an Interim Regulation on Flight Management of RPAS (draft for comments) in January 2018, seeking the views of the civil aviation industry and wider community, such as the military. This interim regulation includes seven chapters, presenting a range of safety-related issues, including RPAS classification, mandatory registration, pilot education and training, airspace, flight plan, commercial operator, role of manufacturers/retailers, and legal liability. It is the first time that China has deployed the management and development of RPAS from the national strategic level. As the highest administrative regulations for RPAS at this stage, it is the regulation that civil aviation authorities must comply with to supervise RPAS.

So far, the Interim Regulation on Flight Management of RPAS (draft for comments) has completed the first round of solicitation of opinions.

In July 2019, the Interim Regulation on Flight Management of RPAS (draft for examination and approval) and regulation description were issued by the Ministry of Justice for further comments before Aug. 2, 2019. This document is the result of the consultation performed with the Interim Regulation on Flight Management of RPAS (draft for comments).

In the airspace management, Interim Regulation on Flight Management of RPAS (draft for examination and approval) requires that the RPAS's flight airspace is classified by the combination of the horizontal protection range for ground target and the restricted height. Under the premise of a clear horizontal protection area, the height of below 50 meters is required for micro RPAS and below 120 meters for light RPAS, which basically covers recreational users.

In the flight plan management, the current policies that all flights should apply for a flight permit in advance have been revised so that micro RPAS, light RPAS, RPAS for agriculture, and some state RPAS do not need to apply for a flight plan when they are flying in a specific airspace (light RPAS and RPAS for agriculture need to report their information in real time). Small RPAS can properly simplify the flight plan approval process when flying below 300 meters.

In terms of the legal obligation, it stipulates that organizations and private individuals flying RPAS are responsible for ensuring flight safety. Except for obvious faults, when an RPAS is involved in an occurrence with a manned aircraft, the party responsible for the RPAS flight shall bear the primary responsibility; if the occurence occured between RPASs, the party that operated in beyond visual line of sight operations (BVLOS) shall bear the primary responsibility or share responsibility.

The draft of China Civil Aviation Regulation Part 92 Safety Management Rules for RPAS (CCAR-92) will be issued after the release of this Interim Regulation on Flight Management of RPAS.

In June 2017, the Standardization Administration Committee (SAC), the Ministry of Industry and Information Technology, the Ministry of Science and Technology, the Ministry of Public Security, the Ministry of Agriculture and Rural Affairs, the General Administration of Sport, the National Energy Administration, and CAAC jointly issued Guidelines for Developing RPAS Standard System Framework (2017–2018 edition) (the Guidelines). The Guidelines establish a two-phase and three-step road map and define the requirements, framework, and implementation methods of the RPAS standard system. The framework will be completed in two phases.

The first phase (2017–2018) establishes a standard system for RPAS and focuses on developing a number of key standards urgently needed by the market and supporting regulatory requirements.

The second phase (2019–2020) will gradually push forward the development of standards. By 2020, the standard system will be basically established and improved, including basic standards, management standards, technical standards, and industry application standards, which will meet the application needs of relevant industries.

Here, the basic standards include terminology, classification, and identification. Management standards include research and development, manufacturing, registration, operation, etc. Technical standards include system, subsystem, and component-level standards, and application standards include different application field standards. Basic standards are mainly national standards, management standards, and technical standards; industry application standards are mainly industry standards.

CAAC's policy is to implement an effective aviation safety regulatory framework to enable the safe and efficient integration of RPAS into the aviation system. To accomplish this, CAAC will develop policy, standards, regulations, and guidance material reflecting an appropriate and proportionate approach to the relevant levels of risk consistent with international best practices.

Integration of RPAS into the system of aviation safety should provide enough flexibility for innovation in the RPAS industry without adversely affecting other airspace users, the traveling public, or posing unacceptable risks to people or property on the ground. CAAC will continue to engage with the International Civil Aviation Organization (ICAO) and other international aviation safety agencies to address key policy issues, including the equitable access to airspace, privacy, national security, and the environment. It is a long-term process to expand the flight activities of civil RPAS from isolated airspace to nonisolated airspace and finally integrate the activities into the national airspace system. The management of RPAS will refer to the existing management system of civil aviation and could be broadly divided into flight standards, RPAS airworthiness certification, market management, and air traffic management.

Classification of RPAS

In Interim Regulation on Flight Management of RPAS (draft for comments) dated January 2018, according to flight safety risks, taking mass as the main index and combining with RPAS performance such as flight height, speed, radio transmission power, and airspace maintenance capability, RPAS are divided into micro, light, small, medium, and large RPAS.

- Micro—RPAS with an unloaded weight 250 grams or less.
- Light—RPAS with an unloaded weight of more than 250 grams but fewer than four kilograms and seven kilograms MTOM.
- Small—RPAS with an unloaded weight of at least four kilograms but fewer than 15 kilograms or 25 kilograms MTOM.
- Medium—RPAS with an unloaded weight of more than 15 kilograms and MTOM of at least 25 kilograms but fewer than 150 kilograms.
- Large—RPAS with MTOM of more than 150 kilograms.

Here, the classification of micro and light RPAS refer to the practices of most countries in deregulating RPAS below 250 grams. The concept of MTOM is mostly used for manned aircraft and is an important indicator for airworthiness certification. Many countries have directly adopted this concept in RPAS. However, as small and light RPAS do not have airworthiness requirements, they may not be able to provide the officially tested maximum certificated takeoff mass. For ease of management, it regards MTOM and unloaded mass as two important classification criteria for light, small, and medium RPAS. Light and medium RPAS should meet two conditions, and small RPAS need only to meet one.

According to the requirements of Advisory Circular Interim Regulations for Specific Category of RPAS Operation (AC-92-2019-01, issued on Feb. 1, 2019) issued by CAAC, RPAS operation management is categorized as follows:

Advisory Circular Interim Regulations for Specific Category of RPAS Operation

Category	Unloaded Weight (kilograms)	MTOM (kilograms)
I	0<W≤1.5	
II	1.5<W≤4	1.5<W≤7
III	4<W≤15	7<W≤25
IV	15<W≤116	25<W≤150
V	RPAS for agriculture and forestry use	
VI	Unmanned airship	
VII	RPAS in categories I and II operated BVLOS	
XI	116<W≤5700	150<W≤5700
XII	W>5700	

According to the operation management mode, civil RPAS are also divided into categories of open, specific, and certified. The specific category RPAS includes Categories III and IV with higher risk of operation and Categories XI and XII with less risk. CAAC believes that the specific category of RPAS should be certificated for operation, while other categories of RPAS do not need to be certificated.

Mandatory Registration

A requirement for RPAS to display registration and/or contact details would assist in identifying owners involved in a reportable incident or accident. On May 16, 2017, CAAC implemented the aviation procedure Regulations on Real-Name Registration of RPAS (AP-45-AA-2017-03, issued on May 16, 2017), which required the manufacturer and owner of a civil RPAS with a gross weight of 250 grams or more to carry out real-name registration effective June 1, 2017. After Aug. 31, 2017, if the real-name registration and registration marks have not been implemented, the flight is regarded as illegal in violation of laws and regulations, and the regulatory authorities will impose penalties according to relevant regulations.

The owner of a civil RPAS includes individuals and organizations. The process of real-name registration involves the manufacturer and the owner to apply for an account on the RPAS Real-Name Registration System (https://uas.caac.gov.cn). The manufacturer fills out the information for its products, and the owner registers the information about the RPAS he or she owns with his or her name. The registration mark picture (including registration number and QR code) given by the system is pasted on the body of the RPAS. The owner must ensure that the registration mark is attached to the RPAS during each operation. In case of sale, transfer, damage, scrap, loss, or theft, the information regarding the RPAS must be updated in a timely manner. After the ownership is transferred, the new owner must register the information regarding the RPAS in accordance with the requirements.

Education and Training

In 2018, CAAC successively issued the management document Interim Administrative Measures for Commercial Flight Activities of Civil RPAS (MD-TR-2018-01, issued on March 21, 2018) and Advisory Circular Regulations for Civil RPAS Pilot (AC-61-FS-2018-20R2, issued on Aug. 31, 2018).

With certain exceptions introduced under the two documents above, commercial RPAS operators must hold a remote pilot license and/or RPAS operator's certificate (RPAS at and above 250 grams). The exception to the pilot license requirement is when an RPAS is being operated in Categories I and II in compliance with the information mentioned previously. To obtain a license or certificate, a person above the age of 16 must have successfully completed a specific training course and passed an examination. Other operations do not require a license or certificate or mandatory education or training.

As of Sept. 1, 2018, the current effective RPAS pilot license issued by the industry association is automatically converted to the RPAS pilot electronic license issued by CAAC. The rights contained in the original license are transferred to the electronic license.

As of Jan. 1, 2019, the applicant's training experience data must be connected to the RPAS cloud system approved in accordance with Advisory Circular Interim Operating Provisions for Low Level Operation of Light and Small Unmanned Aircraft Systems (AC-91-FS-2015-31, issued on Dec. 29, 2015) to meet the application requirements for license and/or rating for instruction received and solo pilot time.

To obtain an RPAS operator's certificate, the following conditions must be met: (a) The entity engaged in commercial activities shall be an enterprise legal person, and the legal representative shall be a Chinese citizen; (b) The enterprise shall have at least one RPAS, and the real-name registration shall be completed in the name of the enterprise in the RPAS Real-Name Registration System; (c) The training institution shall have the training capacity approved by the competent authority or by its authorized institution; (d) Ensuring third-person liability insurance for RPAS. Applicants should apply for the RPAS operator's certificate online through the civil RPAS operator's certificate management system (https:// uas.ga.caac.gov.cn).

The General Aviation Air Operator's Certificate Management Regulations (CCAR-290-R1) include four types of certificates: passengers, cargo, training, and aerial work. Management document Interim Administrative Measures for Commercial Flight Activities of Civil RPAS (MD-TR-2018-01, issued on March 21, 2018) applies only to aerial work and training, excluding passenger and cargo transportation. In order to meet the actual needs of the RPAS operation activities, CAAC approved two pilot operations of logistics and distribution of RPAS in Jiangxi and Shaanxi in August and December 2018. At the same time, relevant legislation was initiated to improve the regulatory system, and the relevant provisions related to cargo transportation will be assessed to determine whether cargo will be regulated in the same regulations.

Operation Management of RPAS

Since various RPAS are operated in different ways and they use much more airspace than manned aircrafts in China, it is necessary to implement categorical management. The management of light and small RPAS could be done in the following way due to the state of development of RPAS technology.

Operation Management of RPAS—Deployment of Geofencing

An electronic geofence is a hardware or software system that is coordinated with a flight control system to ensure a certain delimited area of electronic geographic zones to exclude any intruding aircrafts to maintain the safety of the area.

Under Advisory Circular Interim Operating Provisions for Low-Level Operation of Light and Small Unmanned Aircraft Systems (AC-91-FS-2015-31, issued on Dec. 29, 2015), for RPAS of Categories III, IV, VI, and VII and Categories II and V operated in key areas and in the airport clear zone, the electronic fence should be installed and used.

Operation Management of RPAS—RPAS Registered in Cloud System

An RPAS cloud system (UACS) is a dynamic database system for light and small RPAS operations. This system provides navigation, meteorological, and other services for users and conducts real-time monitoring of RPAS operation data (including operation information, position, altitude, speed, etc.). The RPAS uploads flight data immediately when connecting to the cloud. If an RPAS invades an electronic fence, the RPAS cloud will send an alarm.

Under Advisory Circular Interim Operating Provisions for Low-Level Operation of Light and Small Unmanned Aircraft Systems (AC-91-FS-2015-31, issued on Dec. 29, 2015), RPAS of Categories II and V operated in key areas and the airport clear zone should be connected to UACS or send the position of ground control equipment to UACS at intervals of at least once per minute. RPAS of Categories III, IV, VI, and VII (gross weight of more than seven kilograms) should be connected to UACS and report flight date once per second in populous areas and once per 30 seconds in low population–density areas. RPAS of Category IV should be equipped with passive feedback systems.

For RPAS not registered in UACS, the operator should apply to the authority for approval and provide an effective surveillance method before operation.

Between March 2016, when the first UACS obtained qualification for trial operation, and Dec. 31, 2018, CAAC approved a total of nine cloud systems, including five new UACSs and two UACS updated approval letters in 2018 (see Table 1).

RPAS connected to these UACSs shall upload flight data to the cloud during flight.

In 2017, CAAC conducted research on the cloud data exchange and developed a cloud exchange system for RPAS, through which several UACSs can be connected and real-time data exchange and sharing are realized—making registered RPAS in the same airspace mutually visible.

The RPAS cloud system has been operating for nearly three years in China. Mainly registered in the cloud system are light, small, and agricultural RPAS. At present, these cloud systems have realized real-time monitoring of RPAS position, speed, altitude, heading, registration, etc., and for RPAS invading the electronic fence, it has an alarm function. These systems meet the requirements of the recommended standards of Fence of Unmanned Aircraft System (MH/T 2008-2017) and Interface Specification of Unmanned Aircraft and Cloud System (MH/T 2009-2017). In June 2019, CAAC published the recommended standards of Data Specification of Unmanned Aircraft Cloud System (draft for comments), seeking the views of the aviation industry and community.

In addition, some cloud systems also have relatively rich functions, such as online reporting of flight plans, meteorological services, aviation insurance purchase, operation environment monitoring, and other functions, such as monitoring engine parameters and the temperature and humidity of the surrounding environment.

Most RPAS cloud service providers have also established quality management systems and safety management manuals according to ICAO Doc. 9859 Safety Management Manual.

Operation Management of RPAS—Operator

According to the civil aviation law of China, the operator of a civil aircraft shall be covered by insurance against liability for third parties on the surface or obtain a corresponding guarantee.

Flight Plan Application and Approval Process

The Interim Regulation on Flight Management of RPAS (draft for comments) issued in January 2018 broke through the current requirement that all flights must be applied for in advance and implemented only after approval and appropriately simplified the application and approval process for flight plans in

Approval letter number	*Name of UACS*	*Name of UACS provider*	*Date of approval*	*Note*
01	*U-Cloud*	*Beijing U-Cloud Intelligence and Aviation Technology Co.Ltd*	*Mar. 12, 2018*	*First update*
02	*U-Care*	*Cloud Century*	*Mar. 21, 2018*	*First update*
03	*Flying-Cloud*	*Chengdu Flying General Aviation Company*	*Aug. 31, 2016*	*Expired*
04	*BD-Cloud*	*Beijing Compass Technology Co. Ltd.*	*Aug. 28, 2017*	
05	*5U Cloud*	*Beijing 5U Cloud Big Data Technology Co. Ltd.*	*Jan. 2, 2018*	
06	*KITE BEAM*	*Nanjing Dwing Aviation Technology Co. Ltd.*	*Mar. 2, 2018*	
07	*FindDrone*	*Qianxun SI*	*Mar. 21, 2018*	
08	*UGRID*	*Smart Grid (Beijing) Tech Co. Ltd.*	*Jun. 4, 2018*	
09	*Xcloud*	*Guangzhou Xaircraft Technology Co. Ltd.*	*Sep. 20, 2018*	*For agriculture and forestry's exclusive use*

Table 1

some operation scenarios.

The micro RPAS flies outside the prohibited airspace and does not need to apply for a flight plan, and light RPAS and agriculture application RPAS flying in the appropriate airspace do not need to apply for a flight plan, but dynamic information must be submitted in real time to the supervision platform for RPAS.

In addition, organizations or individuals engaged in other categories of RPAS flight activities must submit an application for a flight plan to the local air traffic control department prior to flight, and the flight plan should not be implemented until it is approved.

Dedicated RPAS Branch—National Aircraft Standardization Technical Committee's RPAS Subtechnical Committee

In December 2018, the first RPAS Subtechnical Committee (SAC/TC435/SC1) of the National Aircraft Standardization Technical Committee was established to be responsible for the development of national standards in the fields of design, manufacture, delivery, operation, maintenance, and management of civil RPAS. In line with the International Organization for Standardization's Technical Committee on Aeronautics and Spacecraft's Technical Subcommittee on Unmanned Aircraft Systems (ISO/TC20/SC16), it aims to promote the development of the industry standard system for RPAS, improve the safety and quality level of RPAS products, and promote the high-quality development of China's RPAS industry.

Air Traffic Management System for Civil RPAS

On Nov. 19, 2018, the test project of RPAS flight management in Shenzhen was launched, and the comprehensive supervision platform was put on line for trial operation. At the same time, the Implementation Measures for RPAS Flight Management was issued in Shenzhen, announcing that the comprehensive supervision platform would efficiently connect users and management departments. The platform mainly consists of modules of airspace management, civil aviation management and flight information service, public safety management, and user service.

Airspace management mainly deals with the functions of airspace planning, approval, release, flight plan declaration and approval, and real-time monitoring of flight.

Civil aviation management and flight information management is undertaken by the RPAS air traffic management information service system (UTMISS) of CAAC (www.utmiss.com). It mainly implements the functions of monitoring information collection and processing, civil aviation flight safety assessment, information transmission, user information management, user and RPAS information verification, and information integration service, etc. It is deployed in the center southern region administration of CAAC, ATMB, the Civil Aviation Shenzhen Administration, and the local air traffic control station. Through communication with the civil aviation service, the public safety service, and other systems, UTMISS provides RPAS flight application information, real-name registration information of inspectors, pilot license information, RPAS airworthiness information, RPAS operator certificate information, and RPAS owner information to all service systems.

Public safety management mainly deals with the functions of public security filing, real-time flight monitoring, and networking of detection and countermeasures equipment, etc.

User service mainly focuses on the functions of user registration, information inquiry, flight plan application, submission of flight dynamic information, and notification and reminder, etc.

The integrated monitoring platform for RPAS takes flight management as its core, including elements such as airspace management, civil aviation management, and public safety management to meet the needs of fast flight approval, real-time visibility of flight paths, rapid verification of control, and release of comprehensive information. Through the platform, the functions and tasks of military, civil aviation, and public security are defined and the coordination relationship is clarified. ◆

Evolution of Mishap Prevention:

Human Factors Evaluation for Unmanned Aircraft Systems

By Elise Lagerstrom, Ph.D., Insitu Inc., Human Factors Mishap Investigator

(Adapted with permission from the author's technical paper Evolution of Mishap Prevention: Application of Human Factors Evaluation Techniques for Unmanned Aircraft Systems (UAS)*, presented during ISASI 2019, Sept. 3–5, 2019, in The Hague, the Netherlands. The theme for ISASI 2019 was "Future Safety: Has the Past Become Irrelevant?" The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)*

Elise Lagerstrom

The aviation safety team at Insitu uses both proactive and reactive evaluation techniques to improve overall product quality and usability. Recently, methods such as focus groups and interviews, a year-round focus on hazard reporting from all employees, and use of the Human Factors Analysis and Classification System (HFACS) in mishap investigations and near-misses have resulted in actionable and functional recommendations.

The most common recommendations generated by these prevention programs center on curriculum/training of pilots and maintainers, pilot experience, gaps between system capabilities and desired functionality, and system documentation.

As a result of dispositioning recommendations to the responsible teams, findings from the programs and methods mentioned in this study have been used to

- correct documentation gaps and errors.
- change autopilot logic for improved integration with manned aviation.
- improve maintenance procedures and documentation.
- modify the pilot curriculum.
- change the user interface to improve pilot situational awareness and monitoring of aircraft function.

Introduction

The evolving root cause of aviation mishaps has been well documented; with technological development, materials and processes become more reliable, leading to decreased material failures and increased relative prevalence of mishaps due to human error. Statistics on the substantial role of human factors in aviation mishaps were first published back in 1993; however, this distribution still holds true today with the latest statistics indicating 70–80% of aviation mishaps are attributed to human error. In manned aviation, the focus of safety and mishap prevention has appropriately shifted to address the human-machine interface (HMI) and usability with advances in technology, such as the glass cockpit, augmented reality, and improved training simulations. However, in unmanned aviation, it could be argued that we lag behind, with a focus on perfecting the airframe, autopilot logic, and performance characteristics to meet varying operational demand. While these advances are essential to safe operations, there is a warped and inappropriate feel that the role of the pilot and safety of the system are somehow less important because of the lack of physical human presence within the aircraft. This attitude is detrimental not only to the development of systems, but also to attempts to integrate the unmanned aircraft system (UAS)/remotely piloted aircraft system (RPAS) into airspace with manned platforms.

Insitu is a company focused on UAS; however, we believe that to be safe and successful aviators, we need to refocus on the pilot. In the last year, we have integrated human factors evaluation techniques and programs, both proactive and reactive, to anticipate the shift in the root cause of mishaps in UAS from material to human-related causes.

Proactive Mishap Prevention Programs

One of the ways we are working to anticipate and prevent future mishaps is by moving to proactive forms of mishap prevention. To do this, we have implemented several initiatives with the goal of identifying and tracking threats before they result in mishaps. Four of these initiatives include a line operations safety audit (LOSA) program with specific focus on UAS, pilot workload and usability assessments, tracking of active and latent conditions using HFACS for near-miss events, and the use of focus groups and user interviews with pilots and maintenance personnel. Each of these methods has provided different and valuable recommendations that can be pushed upstream to design and engineering teams, as well as downstream to the end users.

LOSA

According to an FAA advisory circular, "A LOSA is a formal process that requires expert and highly trained observers to ride the jumpseat during regularly scheduled flights to collect safety-related data on environmental conditions, operational complexity, and flight crew performance. Confidential data collection and nonjeopardy assurance for pilots are fundamental to the process." For successful LOSA program implementation to occur, there must be support throughout the initiating

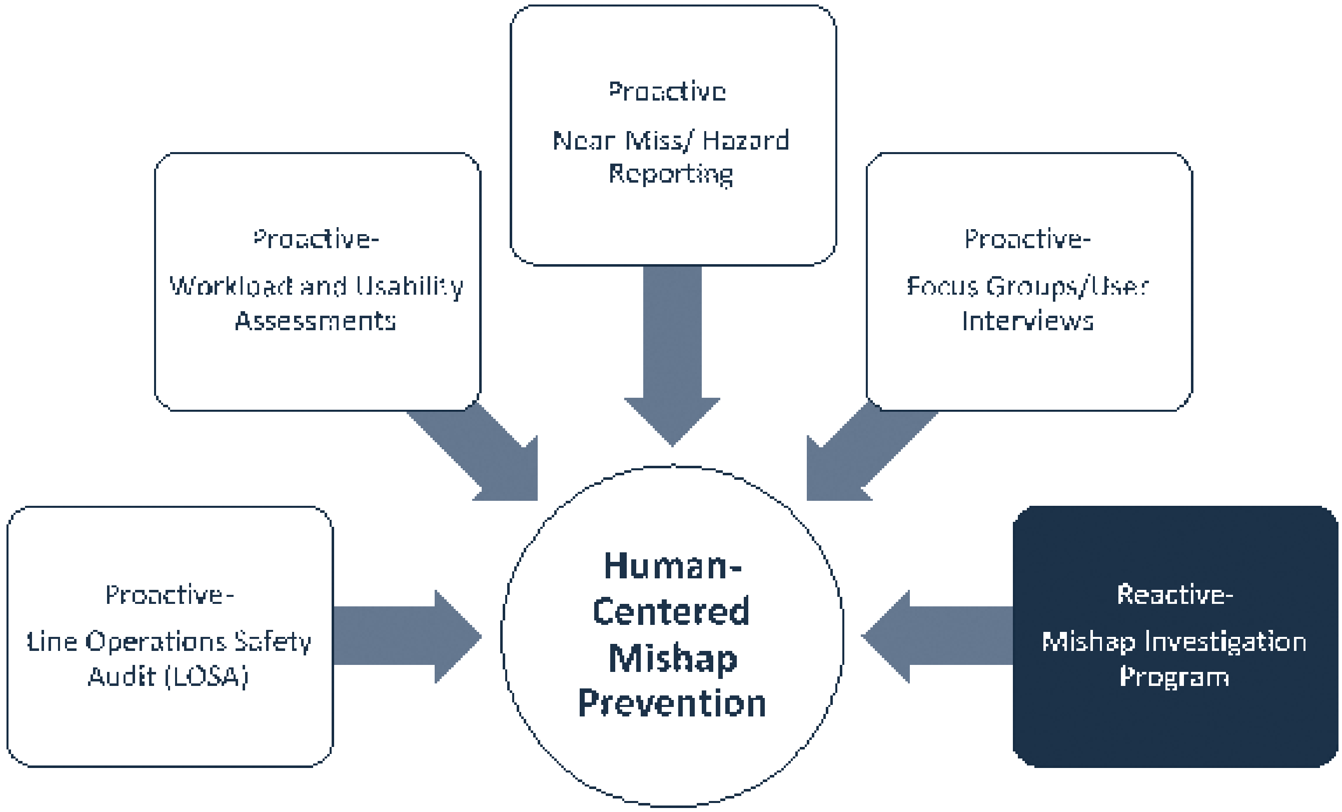


Figure 1. Human-centered mishap prevention.

organization.

The objectives of implementing a LOSA program are as follows:

- To obtain feedback from pilots so that system improvements can be made,
- To obtain baseline data on crew workload and threat management for comparison if and when changes are made to the system,
- To heighten safety and procedural awareness, and
- To reduce the incidence and cost of human error–related mishaps by identifying unsafe conditions prior to mishap occurrence.

At Insitu, successful implementation of the LOSA program is reliant on cooperation and assistance from pilots, training, curriculum development, deployed operations, management, and safety teams. The Aviation Safety Department at Insitu serves as the facilitator of the LOSA program and created training materials for pilots, observation forms, and methods of data management and dissemination of results. The LOSA forms that were created were designed for specific application to UAS. In addition, the LOSA observation forms that were developed are specific to pilot and maintainer actions.

The LOSA observation form for UAS pilots was designed to capture human error and areas for improvement during normal flight operations with emphasis on items that are known to specifically threaten the safety of UAS operations. The LOSA observation form for pilots consists of the following sections: demographic and flight data collection, a written narrative evaluation, behavioral assessment standards evaluation, error identification and management worksheet, and a self-assessment form that is completed by the pilot who was observed. The forms are divided and completed during each phase of flight to distinguish between the unique threats seen during each period.

The LOSA observation form for maintainers is designed to capture human error and areas for improvement during normal maintenance tasks. In contrast to the LOSA observation form for pilots, which makes observations during each phase of flight, the LOSA observation form for maintainers assesses maintainer actions and behaviors during preflight checks, postflight checks, and regularly scheduled maintenance procedures (such as a 50-hour engine inspection).

The LOSA program at Insitu is still in the development phase. The data collection forms, methods, and training materials have been created, but they are still being piloted locally. We are still working to scale and deploy the program to remote sites to achieve one of the defining features of LOSA, which is that audits are completed by peers during actual missions. Before the end state can be achieved, awareness training must be completed with all pilots involved in the program, and more extensive training must be provided to pilots who wish to serve as program auditors. Before conducting this training, we are working to trial the data collection forms and methods during training and simulation flights. These trials, while not providing "true" LOSA observations, have helped to identify deficiencies within the methods, and we have been able to receive feedback from operational personnel on not only the methods, but on how to best implement the program.

Workload and Usability Assessments

Periodically, workload and usability assessments are completed on the user interface. The purpose of the evaluations is to measure pilot workload and subjective usability during various operational tasks. Usually, these tasks and scenarios are designed to verify specific aspects of the user interface for compliance with standards while simultaneously providing feedback, which helps improve the HMI to meet future operational needs and expand system capabilities.

Limitations of the workload analysis are due to sample size, and evaluations thus far having been conducted during simulated flight. While there are benefits to conducting the evaluations in a simulated environment (the main benefit being elimination of mishap risk due to divided attention), the simulated environment does not perfectly mirror the stresses of a live flight or mission scenario.

As a result of the workload and usability assessments, we have received both qualitative and quantitative feedback from operational personnel that has been translated into actionable recommendations for software development.

HFACS for Near-Miss/Hazard Reporting

Insitu has a robust near-miss/hazard reporting system that receives hazard reports (HAZREPs) from multiple different sources. These HAZREPs are categorized, triaged, and dispositioned at a formal review board. During the triage and review process, the identified hazards are screened for elements related to human factors and/or human error. If there is a human component to the identified hazard, HFACS is used to tag and categorize the identified hazard or near-miss.

The HAZREP program is beneficial in that we are able to identify hazards before they result in mishaps; when paired with HFACS, we are able to identify which barriers prevented the hazard from resulting in a mishap. Using this database, successful mitigations can be tracked. A major strength of the program is that it provides an avenue to solicit field knowledge, circumstances, and expert opinions on a recommended path forward for operational concerns.

There have been numerous instances of maintenance errors and near-miss reports being used to create system and procedural change at Insitu. Through use of the HAZREP program, these errors, near-misses, and prevention ideas are evaluated, tracked, and implemented.

For example, the Hazard Review Board received multiple HAZREPs documenting the hazard of not being able to communicate between the ground crew and the ground control system at a site. There was concern that the inability to communicate would cause an inadvertent launch or could result in personnel injury. As a result of the hazard review process, a new radio system with headsets for the ground crew was implemented at the site.

Currently, the most prevalent condition reported using the hazard identification program is the identification of procedural guidance or publications that create an unsafe situation. This type of hazard is commonly identified by either deployed personnel or the Training Department. One of the most challenging aspects of managing the hazard reporting program is encouraging the reporting of problems or deficiencies without creating an environment in which the team responsible for fixing the deficiency feels it is to "blame." This is a fine balance and is contingent on the cultural maturity of the organization. One of the points that is emphasized to reinforce the positive aspects of the program and ensure that the organization is united in trying to accomplish a common goal is to reinforce that every time a hazard is reported using this system it is an opportunity to intervene in a condition that had the potential to result in a mishap. Therefore, by reporting hazards personnel are ensuring a safe work environment for themselves, as well as contributing to an overall organizational mission of reducing the mishap rate.

Focus Groups/User Interviews

As a part of failure review boards spurred by clusters of a specific type of failure, focus groups and user interviews have been used to obtain information from pilots and operational personnel. The best recommendations and discussion thus far have developed out of using a focus group–type session in which questions are posed to groups of operational personnel rather than one-on-one interviews. Using a focus group as a forum, insight is obtained from multiple operational sites at once, and comparison and contrast of the challenges under different conditions is easily obtained. While a standard list of questions is usually followed, when open discussion between operational personnel is facilitated it has been possible to identify similarities (as well as differences) between the failures and challenges occurring at different operational locations or using different product configurations. This information has been invaluable for gathering information on experience and training of personnel, flight operations, and desired software improvements.

Most recently, multiple focus groups were conducted over a period of several weeks to gather information on failures and challenges related to air vehicle recoveries. The targeted focus group participants were pilots and maintainers who had just returned from a deployment. During these interviews, we learned the importance of team composition and the desired skill level of pilots. One of the major topics of discussion was the gap between the idealized (and trained) aircraft recovery schema versus how the UAS pilots were expected to interact with airspace and other aviators. Based on the information provided, changes were made to the software that allows for greater manipulation of the approach corridor and allows the air vehicle to perform more similarly to manned aircraft in controlled airspace. With this expanded functionality, there was also the suggestion for expanded training to improve the pilots' ability and comfort in operating alongside manned aircraft.

Mishap Investigation/Reactive Mishap Prevention

While it is still early in the development and implementation of these proactive initiatives, the process to track and complete recommendations stemming from the investigation of mishaps is well established. Investigations are conducted for all mishaps reported to the Insitu Aviation Safety Department that meet a defined criteria. During the investigations, all evidence that was received is reviewed. This evidence is analyzed for material, environmental, and human-related failures. Assignment of a single type (material, environmental, or human) of failure is often not possible, as the mishaps are due to a combination of conditions that all aligned to create the circumstances in which the mishap occurred. Therefore, the investigator must determine the role and contribution of each type of contributing factor.

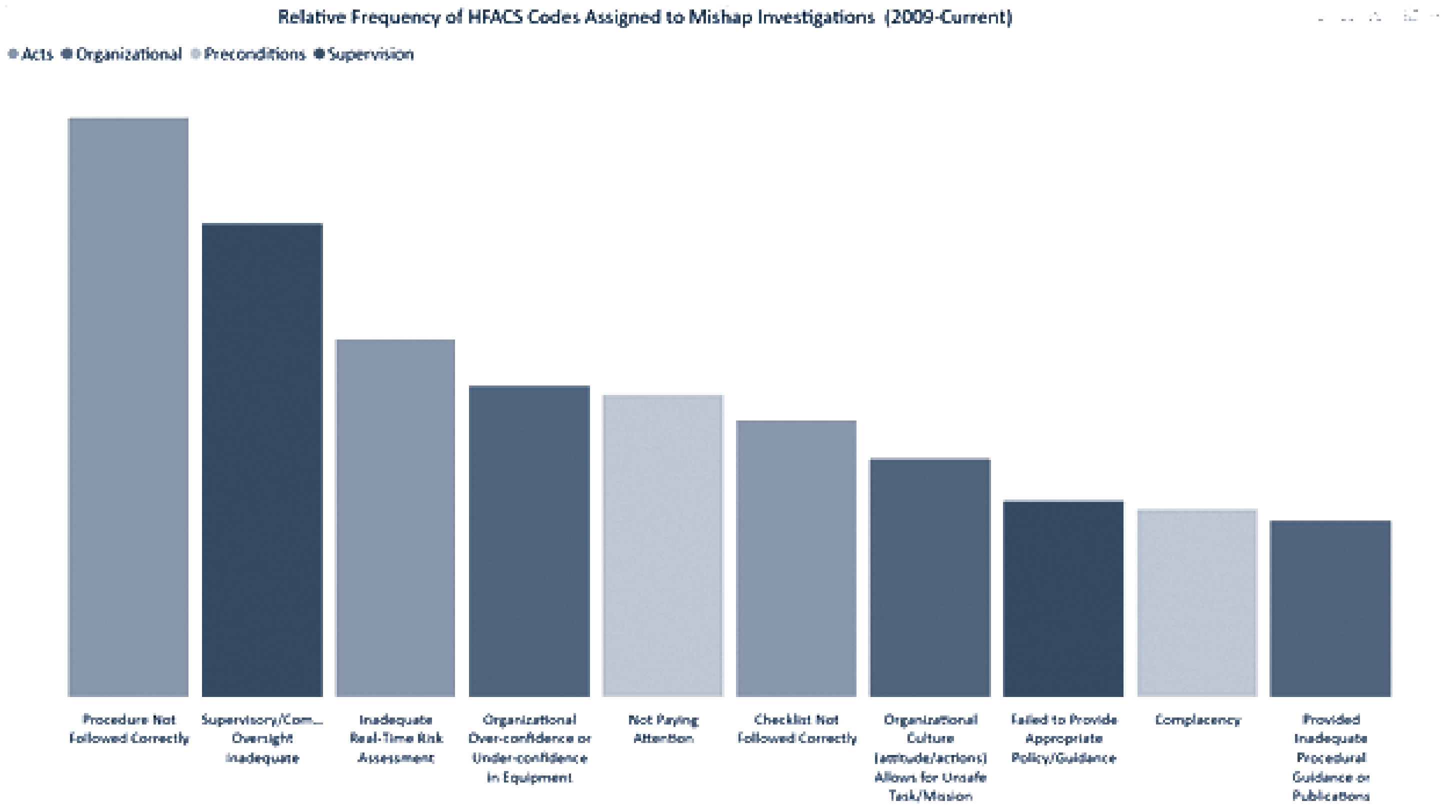


Figure 2: Relative frequency of HFACS codes assigned to mishap investigations.

At Insitu, since 2009 material failures have been identified as the primary cause of mishaps more prevalently than human or environmental causes. However, if Insitu follows a similar path to manned aviation, as aircraft become more (mechanically) reliable, the total number of mishaps will decrease, but the percentage of mishaps caused by human factors will increase.

To aid in the investigation, HFACS is utilized to categorize casual and/or contributory conditions that were identified. The purpose of the identification and categorization of these factors is to identify trends and also to guide the development of recommendations and mitigations. This information is stored within the database and queried monthly to identify trends and push the latest information out to users and development groups.

In anticipation of the transition from primarily machine-related causes to human error mishaps, the causal and contributory factors for mishaps attributed to human error are tracked and further categorized. Failure to follow checklists and procedures and inadequate risk assessment are the leading contributory human factors in mishaps attributed to human error. In addition, at the organizational level, providing inadequate procedural guidance and publications to sites has been identified as a contributing factor to many mishaps attributed to human error.

Conclusion

As a result of the findings from mishap investigations and the proactive mishap prevention programs previously described, recommendations are developed and distributed to accountable departments throughout the company. These recommendations have resulted in changes to the design of the software, autopilot logic, publication updates and changes, training curriculum development, and even improvements to the infrastructure surrounding deployed locations.

One of the complex challenges we identified and anticipate for the future is the interaction between manned and unmanned aircraft. Changes will need to be made to regulations, technology, training, and culture to provide an environment in which both manned aircraft and UAS coexist safely and successfully. As regulations are currently under development across the globe, we are using feedback from controlled encounters to predict and proactively address some of the potential operational challenges. For example, UAS pilots come from a variety of backgrounds and may not have experience in manned aviation. To decrease risk and increase the probability of successful interactions, we are working on ways to develop the curriculum to increase the relative skill level of UAS pilots to make them not simply operators but aviators. In addition, the need for education is two-sided. As with manned aviation, every aircraft has operating limitations. To operate cooperatively, we need to develop communication channels and inform air traffic control and other users within the area of operations on our performance capabilities and limitations.

As time progresses, we will work to improve and mature these programs, building the fundamental structure of a safety management system. One of the greatest challenges is the process to bridge the gap effectively and efficiently between operational personnel and design activities. To be effective, the process to take the feedback and lessons learned and efficiently distribute this knowledge back to areas that can execute change should be scheduled, solidified, and formalized.

In looking to the prevention of future mishaps, the past is anything but irrelevant; however, future safety lies not only in correcting mistakes from the past and preventing reoccurrence, but also in the anticipation of future challenges and threats. ◆

The following article is the final of four essays from the 2019 Kapustin scholarship winners presented during ISASI 2019. 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

Remembering Before the Crash:

Nonvolatile Memory Can Change The Course of an Investigation

By Elise Marie Vondra, University of Southern California

Elise Marie Vondra

In the last 20 years, investigators have made air travel increasingly safer by learning from past accidents. Between 1990 and 1999, 541 fatalities in 34 commercial aircraft accidents occurred, and those numbers dropped to 67 fatalities in eight accidents in the years 2007–2017 (1). Investigators painstakingly find, sort, and analyze data from the aircraft to determine the accident's cause. In the aftermath of an accident, however, news media coverage focuses mainly on two major types of data, the flight data recorder (FDR) and cockpit voice recorder (CVR), publishing articles such as "Crashed Lion Air Plane's Cockpit Voice Recorder Found" (2).

The FDR and CVR seemingly give investigators enough data to work with, yet an increasingly important and more-nuanced source of data comes from nonvolatile memory (NVM) sources on the aircraft. NVM data are stored within the chip of a component; are utilized in avionics such as the GPS, altimeters, and pressure sensors; and survive without a power source. NVM can record data from more flights than current FDRs and CVRs. Currently, the widely used Honeywell Connected Recorder-25 (HCR-25) FDR and CVR store only the last 25 hours of flight data (3). In contrast, an NVM chip on a cabin pressure controller, such as that used on Helios Airways Flight 522, can store more than 300 hours of data (4). As avionics advance, the use of NVM on components and their available storage will increase. The investigator must adapt to find and utilize this data, not only after an accident occurs, but also in preventative measures.

Three accidents, Helios Airways Flight 522 in 2005, Turkish Airlines Flight 1951 in 2009, and a general aviation flight in Papua, New Guinea, in 2009, highlight the importance of NVM and how it can be taken advantage of in accident investigations.

Helios Airways Flight 522

Enroute from Larnaca, Cyprus, to Prague, Czech Republic, a Helios Airways Boeing 737-300 lost contact with air traffic control (ATC) mid-flight. Loss of cabin pressure caused both pilots to lose consciousness. The aircraft flew until fuel starvation, eventually impacting terrain 33 kilometers northwest of Athens, Greece. The Air Accident Investigation and Safety Board (AAIASB) of the Hellenic Ministry of Transport and Communications concluded that the cabin pressurization mode was set to manual control, and both pilots failed to identify any subsequent warnings. The AAIASB supplemented FDR and CVR data with data from the NVM of two cabin pressure controllers. The No. 2 slave controller survived the accident, and investigators sent it to Nord-Micro, the manufacturer of the sensor. It contained more than 301 hours of information from past flights. In comparison, the FDR used in this aircraft contained the maximum of 50 hours of flight data. The extended data allowed investigators to conclude that the pilots' behavior of selecting manual cabin pressure was abnormal, as past flights did not show a pattern of this selection (4).

Turkish Airlines Flight 1951

The use of NVM to determine patterns in data was especially useful in Turkish Airlines Flight 1951. The Boeing 737-800 crashed just under a mile from Runway 18R on approach to Schiphol Airport in Amsterdam, the Netherlands, enroute from Istanbul, Turkey. At the time of the accident, the first officer was acting as pilot-in-command (PIC). The Boeing 737-800 has redundant radio altimeter systems, which default to using the left-hand altimeter. However, before the crash, the left-hand altimeter was incorrectly reading an altitude of -8 feet. Since the PIC was looking at the right-hand altimeter, which was reading accurately, neither the

PIC nor the captain switched the primary altimeter to the right-hand side. Therefore, the B-737 flight computer controlling the autothrottle used incorrect altitude data on approach to the airport. With a reading of -8 feet, the autothrottle retarded for a flare. The B-737 autopilot detected the slow airspeed and pitched nose up for a flare, which caused the aircraft to stall on short final. The FDR contained the past 25 hours of data, but the Dutch Safety Board (DSB) relied on the radio altimeters' NVM to assist. The radio altimeters stored much more data than the FDR, as chips inside each radio altimeter recorded the past 2,000 flights, recording 217 interruptions. These flights contained 58 bad readings on altimeter serial number 1141 and three bad readings on serial number 1157, the failing radio altimeter. Investigators did not find out why the radio altimeter had produced erroneous values; however, the extended NVM on the radio altimeters provided more context regarding the history of the behaviors of the altimeters (5).

GA Flight in Papua, New Guinea

As well as helping investigators in major airline accidents, the use of data from NVM sources is critical in aircraft that do not meet the requirements to carry an FDR or CVR. In 2009, a DHC-6-300 Twin Otter enroute from Port Moresby to Kokoda in Papua, New Guinea, impacted terrain mid-flight.

The DHC-6-300 does not meet the maximum takeoff weight requirement for air carrier operations, negating the requirement for an FDR on board.

Eleven miles south of the airstrip, the aircraft crashed due to controlled flight into terrain (CFIT).

However, the Twin Otter was equipped with a Latitude Technology Skynode S100, a small data-logging device that can be installed in smaller aircraft that do not operate under air carrier regulations. Investigators recovered the device at the accident site and sent it to the manufacturer for analysis. This device stores data regarding takeoffs, landings, ground speed, and GPS position and altitude. The Australian Transport Safety Board (ATSB) used this data to recreate the flight path, with data taken about every seven minutes to track the flight until the crash. It did not rely on other less-factual sources of data, such as ATC recordings or eyewitnesses (6).

In each of these cases, NVM provided additional data and context to accident investigators. While more-limited FDR recording data may describe what occurred during the accident, NVM can provide information from many previous flights, revealing trends showing why an accident ultimately occurred. In both Turkish Airlines Flight 1951 and Helios Airways Flight 522, NVM data provided trends that investigators utilized and applied to existing and future aircraft. As more sensors become digitized, and potentially contain NVM, investigators can, and must, find, read, analyze, and act upon the data contained in them.

The investigator can also look to other sources of NVM that are not installed in the airframe. For example, passengers' cell phone data may be used to track GPS and accelerometer data. This has been used by the U.S. National Transportation Safety Board (NTSB) in railroad accidents—the NSTB analyzed data from 80 different passenger devices in the investigation of the Amtrak 188 derailment in Philadelphia, Pennsylvania, U.S.A., in 2015 (7). This technique can be implemented into aviation applications so that investigators can collect more data leading to the incident. Personal devices may also give investigators an eyewitness view of the flight. For example, if a passenger filmed the cabin in extreme turbulence, this could give investigators an idea of flight conditions before the accident occurred.

New measures are being taken to improve flight data by component manufactures. General Electric is placing its new enhanced airborne flight recorder (EAFR) into the Boeing 787 and 777x fleet. The EAFR will allow 50 hours of recorded memory, compared to the 25 hours of the HCR-25 (8). Although this is an improvement, the EAFR does not replace the detailed and larger storage of NVM on other smaller components.

A component that would greatly benefit from NVM analysis is angle-of-attack (AOA) sensors on aircraft. With the current controversy surrounding the Boeing 737-MAX 8 accidents involving Lion Air in 2018 and Ethiopian Airlines in 2019, investigators would gain information from looking at NVM of AOA sensors of all previous MAX 8 flights and other airframes that use an AOA indicator. Currently, the main source of data on AOA sensor failures is pilot-driven NASA reports in the Aviation Safety Reporting System (9). Reliable, robust, and factual data from NVM would assist investigators, manufacturers, and carriers in improving safety and reliability of new sensors.

As well as providing aircraft investigators with data that would otherwise not be available due to regulations, as in the DHC-6-300 case, NVM also allows larger-scale trends to be seen in investigations. In the Turkish Airlines Flight 1951 accident, the radio altimeter NVM provided more context to the crash, showing a pattern of incorrect altimeter readings that went uncorrected. Adding NVM to new components can also assist in using past flights for current accidents. Learning from these accidents, a challenge to investigators, and especially operators, is to collect and analyze this data more frequently. Taking proactive measures in data analysis of components will not only assist carriers in preventative measures, but also can be applied at a multicarrier scale, thus assisting component manufacturers in innovating safer technology and assisting the trend of creating safer air travel for all. ◆

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ACCIDENTS PAST, ACCIDENTS FUTURE:

SAFETY IN THE AGE OF UNMANNED AVIATION

(Adapted with permission from the author's technical paper Accidents Past, Accidents Future: Safety in the Age of Unmanned Aviation *presented during ISASI 2019, Sept. 3–5, 2019, in The Hague, the Netherlands, by Gerard de Rover. The theme for ISASI 2019 was "Future Safety: Has the Past Become Irrelevant?" The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)*

Gerard de Rover

Thomas A. Farrier

The theme of the 2019 ISASI annual seminar is "Future Safety: Has the Past Become Irrelevant?" This is a timely and necessary issue to take up in the context of unmanned aviation. There are few directly relatable lessons learned upon which to base a path forward for the certification and operation of remotely piloted aircraft systems (RPAS). Still, countless analogies can and should be drawn to the evolution of *manned* aviation and the history of major aviation accidents to date in considering how RPAS should join and participate in the greater flying community. At the same time, the historical record is extremely important as a means to avoid repeating in the unmanned domain errors first identified in manned aviation.

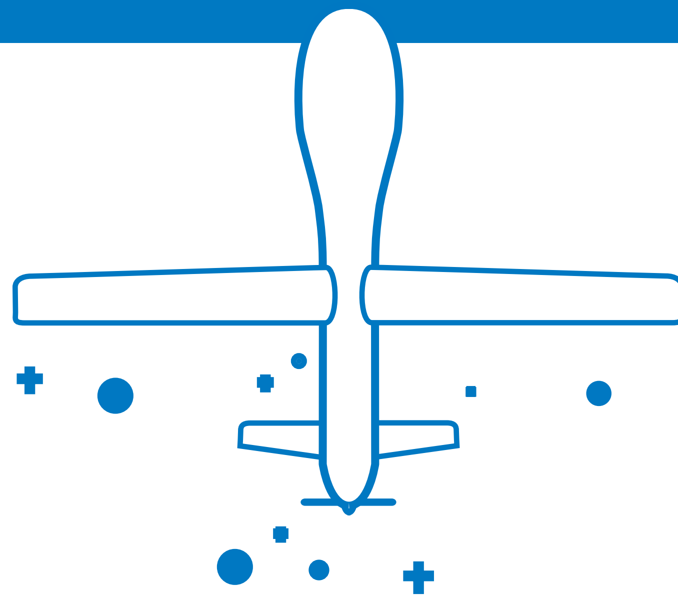
Throughout the first century of powered flight, aviators and engineers constantly ran afoul of what they did not know about the flying environment, the demands it put on both pilots and aircraft, and the complexities of keeping ever-faster and more numerous aircraft safely separated from one another. Painful but essential lessons were learned through accidents and their investigations. Perhaps most important, the speed with which aviation expanded and evolved tended to reduce the likelihood that important preventive measures, once implemented, subsequently would be abandoned. Lessons learned throughout aviation's brief history for the most part have *stayed* learned.

Against this backdrop of hard-won experience, it seems reasonable to assume that new entrants into the aviation environment would seek all available information to understand the hazards, and regulators would ensure that the rules under which new entrants are granted access would be applied fairly and uniformly. Indeed, this has been the case for generations as the framework for allowing experimental and homebuilt aircraft and less comprehensively trained pilots has evolved to incorporate all safely into the overall aviation system.

At its core, unmanned aviation is just another form of aviation, and unmanned aircraft are just a different breed of aircraft. However, the "unmanned aviation sector" is a very different collection of interests, with very different priorities from the pioneers of manned aviation. Its proponents and practitioners have consistently sought to operate as free of regulatory constraints as they can.

Two seemingly conflicting arguments regarding unmanned aviation frequently are raised in advocating for widespread expansion of the unmanned sector. The first is that RPAS can safely be employed in support of a wide range of "integrated" operations, including those currently carried out by manned aircraft. The second is that unmanned aircraft should be allowed to operate at will in any class of airspace, with minimal obligation to adhere to existing rules governing pilot qualification, system certification, aircraft equipage, or even the conduct of aviation operations themselves.

In consideration of these two contradictory perspectives, this paper seeks to reemphasize the importance of history in the growth of unmanned aviation by addressing two key questions with respect to the relevance of past experience:



By Thomas A. Farrier, Chair, ISASI Unmanned Aircraft Systems Working Group, and Principal Safety Analyst, ClancyJG International. Gerard de Rover, Defense Safety Inspector, the Netherlands, presented this paper during ISASI 2019.

Should lessons from past accidents, or even very recent accidents, involving manned aircraft be applied to making unmanned aviation safer?

Are past accident scenarios in danger of being repeated due to the expansion of minimally regulated unmanned aircraft operations in the midst of manned aircraft?

Safety Developments in Manned Aviation: A Brief Overview

The successful growth of aviation always should be looked at through the prism of the advances in safety that supported its progress. The viability of *commercial* aviation itself is directly traceable to public confidence in it as a safe and reliable form of transportation. If aircraft accidents continued to occur at the rates seen during the 1930s, the commercial airline industry itself never would have been more than an expensive and risky niche instead of an integral part of global commerce.

It always is appropriate to revisit how the current level of safety in aviation has been achieved, including why we do some of the things we do in certifying aircraft and regulating their operations. Many accidents that led to new rules and preventive measures have themselves receded into the past, so it is valuable to be reminded from time to time that little in the body of rules governing aviation is arbitrary or capricious

Consider how aviation and aircraft benefited from examination of safety needs identified through crashes and their investigations. There always has been overlap among these issues, of course, but the challenges to be dealt with moved forward along the following general lines:

- Make airframes strong enough to withstand the stresses of flight.
- Make engines as reliable as possible.
- Find ways of making operations at night and in adverse weather practical and safe.
- Find ways of protecting the occupants of aircraft from harm during normal and adverse conditions.
- Develop means of managing growing numbers of aircraft in the vicinity of airports.
- Develop means of monitoring aircraft movements over large distances and long routes.
- Identify areas requiring surveillance to keep aircraft separated.
- Identify environments within which civil and military operations might come into conflict and develop rules and procedures applicable to both.
- Establish requirements for IFR and VFR operations that protect the former while enabling the latter.
- Establish requirements for airspace based on the control and safety challenges that different densities and complexities of traffic can create.

Each of the above has seen incremental and occasionally revolutionary improvements over time, often resulting in both safety *and* economic benefits. For example, aircraft construction techniques have become steadily more sophisticated, increasing strength and occupant protection while reducing weight. The incorporation of turbojet, and later fanjet, technology into airliner design allowed maximum gross takeoff weights and corresponding cabin and cargo revenues to increase, even as their relative simplicity increased their reliability and, eventually, their efficiency. Communications, navigation, and surveillance capabilities have evolved—sometimes individually, sometimes in parallel—to make air traffic management steadily more efficient while providing both greater system capacity and safe separation.

Sharpening the focus on safety, new aircraft are certified in consideration of experience accumulated over time. Those incorporating new materials or manufacturing processes are subject to close review of their novel attributes and have to prove their safety against long-standing standards suitably adjusted to gauge *performance* as opposed to conformity to possibly outmoded guidance. This is a realistic approach to balancing the need to minimize risk with the need to encourage innovation, again developed through careful consideration and years of experience adjusting certification standards as needed in response to both identified hazards and new technology. *The past matters.*

Are Manned and Unmanned Aircraft Different?

As we move from the development of manned aviation toward the blossoming of unmanned aviation, this would seem to be a purely rhetorical question with an obvious answer. Unmanned aircraft are dependent on either extensive and inflexible preprograming or a two-way datalink allowing a "remote pilot-in-command" (RPIC) to control and maintain situational awareness in the operation of the unmanned aircraft. Unless an unmanned aircraft is explicitly designed and expensively equipped to clear its own flight path, it *must* have either a functioning datalink or totally segregated or protected airspace to allow the RPIC to avoid in-flight conflicts or even midair collisions with other aircraft. Clearly, unmanned aircraft are different from manned aircraft, right?

The real-world perspective on these differences—each of which represents a limitation that is not necessarily compatible with how the current aviation system works—is more nuanced, seeking to accommodate unmanned aircraft *despite* their limitations. However, such a supportive approach also provides potentially unwarranted latitude to unmanned aircraft for shortcomings that would be completely unacceptable for manned aircraft.

In many states, an unmanned aircraft simply is, by definition, "an aircraft." Various qualifiers often are added to that fundamental proposition to account for the limitations mentioned above, but the idea behind starting with the same basic definition is that existing operating rules and certification standards rules can (and should) be applied equally, regardless of whether an aircraft has a pilot aboard or on the surface of the earth.

This ideal environment has yet to be achieved. There is little motivation on the part of the unmanned aviation sector to pursue it, especially to the extent that mandatory equipage associated with specific classes of airspace would cost money to install and more money to make operate through satellite-based datalinks or terrestrial networks. It also would reduce range, endurance, useful payload, or all of the above. To the unmanned aviation sector, "integration" often is seen simply as an alternate term for "access to desired airspace," not participation in the existing aviation system.

One of the major advantages of unmanned aircraft systems (UAS) is that they cost less to build, less to maintain, and less to operate than manned aircraft. These savings often are achieved at the expense of being significantly less capable than the manned aircraft whose airspace they share. However, in facilitating more widespread operations of RPAS regardless of their differences, there is the not inconsequential precedent of permitting some activities that are known to be more hazardous than others based on "societal benefits" asserted to justify them.

As the International Civil Aviation Organization (ICAO) UAS Toolkit observes, "As a regulator, recognizing the societal benefits of UAS and the need to facilitate operations in a safe manner are key and include humanitarian efforts, search and rescue, firefighting, infrastructure monitoring, and research and development [R&D]. Operations limited to VLOS [visual line of sight] operations may limit benefits obtained by carrying loads or discharging substances (e.g., crop dusting, insect control)." Of course, this perspective sidesteps such practical implementation considerations as both manned and unmanned aircraft performing the same operations in the same airspace at the same time and is essentially silent on the larger question of *risk*.

In 1962, ISASI's esteemed founder, Jerome Lederer, presented a lecture on "Perspectives in Air Safety" on his receipt of the Daniel Guggenheim Medal from the American Society of Mechanical Engineers. He asked a number of questions about risk throughout this talk, all of which resonate in the current debate about unmanned aviation; for example, when considering instances in which a production aircraft is found to need a safety-related modification.

The aviation industry resents and protests overregulation and is prone to combat detailed regulation of the nature that would have overcome such a deficiency. But what is the Federal Aviation Administration (FAA) to do when it finds good safety practices developed by one organization not adopted by others, yet both comply with the regulations?

Should the government, in such cases, step in retroactively to correct a known hazardous situation by changing the regulation, making it more specific? One should it be careful not to discourage original thinking, imagination, and ingenuity, which may lead to improved practices? Should the public, therefore, be asked to assume some risks for the sake of progress? The solution to such problems should not lie entirely in the domain of government regulation in a free society.

It is important to acknowledge that a very high–level risk decision has already been made regarding unmanned aircraft operations: *they are permissible and will be allowed to continue*. From a "prevention" perspective, this is by no means an inconsequential part of the landscape.

There is no doubt that some types of aviation operations undoubtedly are safer to carry out using unmanned aircraft than is the case with manned aircraft, even using relatively simple RPAS. It also is undeniable that the lack of a human life at risk aboard an unmanned aircraft allows a different perspective on how and from what platform such operations should be carried out. To date, only a bare handful of accidents has been attributed to manned and unmanned aircraft sharing the same airspace while operating under different rules. However, such occurrences are easy to envision as UAS operations become more common as long as manned and unmanned aircraft are regulated and operated differently.

Thinking About the "Manned" Past to Prepare for the "Unmanned" Future

At this point, it may be best to restate the first of the two questions asked at the start of this paper as "In what ways do UAS need to be more or less the same, in terms of capabilities and operating rules, as manned aircraft in the interests of aviation safety?" To date, there is no generally accepted answer to this question. This is fertile ground for exploring through the lessons of manned aviation and historical accidents.

To start with, consider two propositions:

- What has come to be considered a shared perspective on aviation safety—a common basis for a "safety culture"—is *not* shared by the unmanned aviation sector except to the extent it is obliged to conform to it.
- A complex system like aviation is only as safe as its least safe component.

The first proposition might be hotly contested by the more professional operators and manufacturers of UAS. They could argue, rightly, that they do whatever is asked of them to gain access to airspace. This is true but somewhat disingenuous. Unmanned aircraft cannot conform to many rules of certification or operation currently in force, meaning they must seek permission to operate that is conditioned by mitigations for their various limitations (or that simply accepts the increased risk associated with them). Since unmanned aviation business models and risk calculus are quite different from those of manned aircraft manufacturers and operators, they tend to seek to avoid complying with any requirements not explicitly for the safety of the overarching aviation system and all of its stakeholders.

Manned aircraft pilots are rational actors; they have never been big fans of dying. Aircraft manufacturers are rational actors; they never have been interested in seeing large judgments against them for unreliable designs that have led to losses. Commercial air carriers are rational actors; they will not engage in operational behavior that is likely to place their passengers in jeopardy or even to make them uncomfortable in flight.

In unmanned aviation, risk decisions are driven by different considerations, and the priorities of the manufacturers and operators come from a significantly different direction. If one digs deeper, it becomes clear that, from a regulatory perspective, there is a certain logic in placing less of a burden—a "price of admission," if you like—on RPAS operators willing to accept a certain amount of loss in the course of their operations, as long as those operations do not pose a hazard to the general public or to other users of common airspace.

However, problems arise when lessons from the past that speak to current or emerging hazards are not recognized as such, and a hands-off regulatory approach can result in minimally regulated operations interacting with those regulated on the basis of previously identified need. The present interest in enabling and encouraging the growth of unmanned aviation means RPAS are being regulated with as light a touch as possible, often with the regulators taking on more risk on behalf of the public than would be considered acceptable for manned aircraft and operations.

While this pattern of benign neglect may survive the first catastrophic accident directly attributable to an unmanned aircraft, it will be unlikely to survive a second. Public outcry for rapid, decisive, and effective action will then place national aviation authorities in the difficult position of having to justify their previous risk decisions (economic benefit to the UAS sector versus risk to existing stakeholder operations).

More important, however, is the likelihood that the permissive status quo no longer would be acceptable to the general public. Identifying and implementing credible preventive actions will be essential to restoring public confidence in regulators and minimizing overreactions that actually could harm the unmanned sector more than the laissez-faire approach has helped it. This is where lessons learned from past accidents involving manned aircraft will have to be *relearned*.

The Lessons of History

Since the aviation enterprise as a whole is notoriously slow to act on safety concerns until catastrophes force action, the air safety investigator community needs to be ready to highlight where UAS development and certification requirements have diverged from those of manned aircraft. Past accident reports will need to be dusted off and reexamined as "new" unmanned aircraft accidents, or those where unmanned aircraft are involved, occur in which long-standing adjustments have been made to rules governing manned aircraft.

For this approach to bear fruit, however, it is crucial to consider *how* those manned aircraft accidents occurred, along with the specific changes made to aircraft, the regulatory environment, human-machine interfaces, and pilot training and certification that arose from their investigations and recommendations. The fundamentals—the nature of known risks and the detailed sequence of events documented in similar previous accidents—will be critical in such cases.

Both regulators and the general public often forget that many aviation-related rules have been written in blood and derived from accident investigation recommendations. In the aftermath of aircraft accidents, air safety investigators often are obliged to consider both previous risk decisions and prior accident investigations whose recommendations were not acted upon. It would seem prudent to do likewise in consciously addressing the latitude accorded unmanned aircraft in "growing the sector" before the pressures and passions of a new investigation come into play.

ICAO's UAS Toolkit offers a good starting point for discussions between air safety investigators and regulators: "States will want to make key policy, technical, regulatory, and programing decisions for UAS operations. A determination will need to be made as to what extent UAS regulatory proposals will need to adapt to conventional aviation rules, parameters, procedures, and practices. Consideration should be given to whether existing standards and regulations that govern the operation of manned aircraft can be leveraged, while also addressing the specific and unique needs and characteristics of UAS. When building a regulatory framework for UAS, it is important to ensure that the new regulations do not contradict existing aviation regulations."

If it is not possible to examine the course of unmanned aviation's growth in the greater airspace system prior to an accident, air safety investigators will need to have done at least a little advanced thinking about how to proceed. The objectives of the accident investigation process can be summarized in two straightforward steps: identify causes and make recommendations to prevent recurrence. Accidents involving unmanned aircraft—especially where loss of life occurs—will require two additional steps:

- Determine whether the sequence of events might have been different had a manned aircraft been the subject of the investigation.
- Determine why any difference between manned and unmanned aviation requirements or rules identified in the sequence of events exists.

As observed above, it has been critical to accident investigations over time to identify instances in which the act of flying itself has encountered unknown hazards and the expansion of aviation has created unrecognized hazards. In the past, the governing principle was "You don't know what you don't know." In future investigations involving UAS, it is likely that at least some of the accident sequence will be uncomfortably familiar and the question to be answered might be "Why didn't we see this coming?"

The Power of Analogy

While I prepared this paper, it became clear to me that it can be difficult to align previous accidents and preventive actions involving manned aviation against the unmanned sector. It would be a relatively simple matter to inquire into an accident involving, say, an unmanned aircraft lacking required two-way communications and a transponder colliding with a properly equipped manned aircraft in controlled airspace. The air safety investigator simply would ask why the former was operating under less-stringent requirements than the latter and place the decision made and their consequences in their proper chronological perspective.

However, if one applies the principles of system safety in reverse, it is clear that rules and training typically are the last hazard controls to be imposed on a system. They typically are far less effective than those associated with earlier stages in the life cycle—developing warning systems, modifying a system to eliminate a hazard, or, most desirably, designing the system to avoid encountering the hazard in the first place.

Many of the design decisions that have resulted in unmanned aircraft not having air traffic–related avionics—or in some cases lacking redundant controls, standardized pilot interfaces, and other features commonly found aboard manned aircraft—are a direct result of how UAS are certified (or not certified). In other instances, it is the nature of unmanned aircraft themselves (lacking a pilot on board who can assume control of an aircraft in an emergency, directly perceive the environmental conditions affecting it, etc.) that can result in an unmanned aircraft becoming unrecoverable, experiencing a progressively deteriorating condition or system failure, or otherwise operating in a manner counter to that intended. For these reasons, it is worthwhile to consider *outcomes*—some of which have been declining steadily for decades—against potential new sources of failures or initiating events that can lead to those outcomes.

Most categorization approaches to accidents have relied on identifying types of events that the aviation community wants to reduce or prevent. For example, the CAST (Commercial Aviation Safety Team)-ICAO Common Taxonomy Team list of aviation occurrence categories includes more than 30 types of events. Only about half of these would seem to be of importance to regulators or RPAS operators simply because they do not have to worry about the lives of people aboard their aircraft (yet), and the latter's risk tolerance for certain types of losses is correspondingly higher.

At the same time, this taxonomy, like so much of the current aviation enterprise, is based on certain assumptions that have become embedded in aviation thinking through decades of experience and common practice, including some based on accident experience. As such, it does not readily highlight certain types of accidents whose underlying causes might derive from the uniqueness of UAS, except in very general terms. Some creative thinking, and a fairly detailed understanding of how UAS work, must be applied to "occurrence-based" templates. This may be done prior to or in the midst of an accident investigation, but some preparation is needed to engage in such "what if" strategizing effectively.

As an example, the current emphasis of ICAO's Global Aviation Safety Plan is on improving runway safety, reducing controlled flight into terrain (CFIT) accidents, and reducing loss of control in-flight accidents. EUROCONTROL maintains lists of exemplar accidents associated with each of the above that can be found on www.skybrary.aero. Interestingly, these three types of accidents have been quite resistant to preventive efforts over time, but not for lack of attention paid to them.

For Skybrary, EUROCONTROL had no difficulty assembling a representative list of fatal CFIT accidents solely from occurrences since the beginning of the 21st century. The list of runway operations accidents is much longer and includes a number of events that fairly may be considered "landmark accidents," e.g., the Tenerife tragedy, a Boeing 737 landing on top of another aircraft in Los Angeles, California, U.S.A., and other accidents involving occupied runways and miscues by pilots and/or air traffic controllers.

CFIT accidents would seem to be unlikely in routine RPAS operations, especially those using platforms that are equipped with comprehensive position tracking provided to their RPICs. Now, think about what happens if the command and control (C2) link fails and the aircraft reverts to a preprogramed mode of operation ("lost link profile"). Terrain awareness and warning systems (TAWS) are neither typically provided nor mandated for any type of RPAS. So given that a C2 link failure takes the RPIC entirely out of the control loop, and the aircraft might "decide" to take up a heading, airspeed, and altitude from its present position that would take it to a preprogramed point in space, regardless of the possibility of intervening terrain or surface features, how unlikely might an RPAS CFIT be?

Runway environment hazards pose a different set of challenges for unmanned aircraft. C2 links tend to be bandwidth-hungry, meaning only flight-critical functionalities might be in the "protected spectrum." If the only camera aboard is part of an unmanned aircraft's payload, it may not be available for ground operations or may not provide an adequate field of view for safe taxiing. If towed into position on an active runway, RPAS may interfere with other operations or require other aircraft to yield to them.

On final approach, an unmanned aircraft may directly observe its touchdown point, or it may fly in a more or less purely automated mode to a GPS-defined touchdown point. In other words, mixed UAS and manned operations at an airfield could result in a whole range of challenges distinct from those that have occasioned such concentrated attention on runway safety over time.

Perhaps most interesting from both historical and prevention perspectives in the context of unmanned aviation is the Skybrary recap of causes seen in a whole range of "loss of control–inflight" (LOC-I) accidents, which includes all of the following:

- Loss of situational awareness.
- Low-level wind shear or higher-level clear air turbulence.
- Structural or multiple powerplant damage (including that suffered during midair collisions).
- Intended or unintended mishandling of the aircraft.
- Attempted flight with total load or load distribution outside of safe limits.
- Unintentional mismanagement of aircraft pressurization systems.
- Takeoff attempts with ice contamination.
- Airframe ice accumulation/significant loss of power attributable to engine icing
- Attempting to maneuver an aircraft outside its capabilities to resolve a prior problem.
- In-flight fire.
- Fuel exhaustion or starvation.
- False instrument readings.
- Wake turbulence.

- Pilot-induced oscillation.
- Malicious interference.

When one familiar with UAS looks at this list, it is immediately obvious that UAS are vulnerable to many of the same conditions, albeit for many different reasons. Chief among them is the RPIC's inability to directly perceive what is happening to the aircraft from moment to moment. However, even as work continues on addressing these issues in manned aviation, it is clear that preventive or corrective measures that might be effective in that domain may be completely inadequate for unmanned operations.

One of the great virtues of unmanned aircraft is that many are inherently *more* stable than manned aircraft under normal conditions. Onboard automation provided in many makes them extremely effective at stabilizing themselves, responding to transient conditions that might take them off their programed course, etc. However, some of their design features—such as supercritical wings and satellite antennae subject to "fuselage blanking" in some attitudes—render them vulnerable to unexpected departures from controlled flight.

Experienced UAS pilots often can diagnose structural problems, inadvertent gear extensions, and the like through close monitoring of the need for unusual throttle settings, higher than normal fuel consumption, or a constant need for heading or altitude corrections.

Summing up

Current conversations about the effects of unmanned aviation on airspace include a significant amount of incompletely informed—and occasionally misleading—blurring of existing distinctions between "small" RPAS and larger unmanned aircraft seeking to operate side by side with other aircraft, especially in controlled airspace. There is a not inconsiderable amount of risk associated with those at the small end of the size and weight spectrum interfering with terminal operations at low altitude, especially when permitted to operate in that environment more or less at will and without the possibility of being "seen" either visually or electronically. Addressing the hazards those operations present mostly will be a matter of looking at the history of midair collisions, rules (including mandatory equipage) developed over time to prevent them, and the deference such operations receive and should receive in that environment.

On the other hand, unmanned aircraft asserting a need or a "right" to operate amid other aircraft, whether receiving air traffic services or flying purely under some interpretation of "visual flight rules" (VFR), represent an entirely different challenge. Current aviation stakeholders can and should consider the rules they are required to follow; regulators must take an objective look at how much relief from rules unmanned aircraft operating in shared airspace should enjoy and how much is warranted. In making such determinations, the past will continue to matter.

Finally, attentive readers undoubtedly have noticed that the second question posed at the start of this paper has yet to be directly addressed: Are past accident scenarios in danger of being repeated due to the expansion of minimally regulated unmanned aircraft operations in the midst of manned aircraft?

The author's view is that the answer to this is a qualified "yes." The protections built into the present-day aviation system are far more robust than they used to be, although the foundation of RPAS "detect-and-avoid" technologies rests on understanding that it is not enough for unmanned aircraft to "see" only aircraft emitting transponder or Automatic Dependent Surveillance–Broadcast (ADS-B) Out signals; they must be able to actively detect nonemitting aircraft as well.

Current-generation transport-category aircraft use aircraft collision avoidance systems (ACAS) and only can detect aircraft equipped with transponders. Therefore, it is possible to envision RPAS given relief from the requirement to be equipped with such avionics on the basis of their not being designed or certified with them. The current architectures of both the Single European Sky ATM Research (SESAR) Joint Undertaking and the U.S. next generation air transportation system (NextGen) heavily rely upon participating aircraft being comprehensively equipped to serve as interactive nodes of trajectory information upon which optimal clearances for all aircraft may be based. Again, if equivalent equipage requirements are not imposed upon unmanned aircraft, they will be effectively invisible to all other aircraft in the system.

It is possible to envision a scenario

"The protections built into the present-day aviation system are far more robust than they used to be, although the foundation of RPAS 'detect-and-avoid' technologies rests on understanding that it is not enough for unmanned aircraft to 'see'only aircraft emitting transponder or Automatic Dependent Surveillance–Broadcast (ADS-B) Out signals; they must be able to actively detect nonemitting aircraft as well."

similar to that seen in the tragic 1986 collision of an Aeromexico airliner and a general aviation (GA) aircraft over Cerritos, California. The former was operating under instrument flight rules in the Los Angeles terminal control area (TCA), the predecessor to the current Class A airspace; the latter was operating legally under VFR but strayed into the TCA. Most GA aircraft at that time lacked Mode C pressure reporting transponders, and the profusion of 1200 VFR targets flying under the TCA boundaries complicated the air traffic controllers' task immensely.

The Cerritos accident resulted in quite a few changes in the U.S., including creation of the "Mode C veil" concept and more-stringent communications requirements for VFR aircraft flying in Class B and C airspace. However, it also highlighted the distraction inherent in having numerous transponder targets flying outside airspace for which ATC was responsible. The potential for repeat accidents led many facilities to suppress display of targets below a certain altitude to avoid clutter, which in turn may indirectly have led to the FAA's new guidance to controllers that air traffic services are not provided to unmanned aircraft below 400 feet AGL.

Small unmanned aircraft bring with them their own unique issues, but also can be managed to some extent by keeping them as segregated as possible from manned aircraft. This approach cannot work for RPAS flown *among* manned aircraft. In those cases, history has taught many lessons that apply to all flying, regardless of the pilot's physical location. The aviation community would be wise to reflect on them as unmanned aircraft operations continue to expand. ◆

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Please ensure your listing on the *Forum* "ISASI Information" pages and on the Society website is accurate and current. Send any required corrections to ISASI@erols.com. ◆

Major Safety Agency Changes in Argentina

Daniel Barafini, president of the Society's Latin American Regional Council, reports that there has been a reorganization among Argentine government agencies responsible for aircraft accident investigation. A new agency was created as a multimodal organization that will investigate aviation, highway, railway, and marine accidents and events. The new agency is Junta de Seguridad del Transporte (JST-Transportation Safety Board). The Junta de Investigación de Accidentes de Aviación Civil (JIAAC), which was covered in the April–June 2020 issue of the *Forum*, is now the National Department of Investigations.

Barafini notes that he will no longer be in charge of the National Investigation Department, but will be the safety and accident investigation advisor for the JST and will assist the transfer of aircraft accident investigation expertise and experience to the other transportation modes for which JST is now responsible. ◆

ESASI Provides Summary of 2019 Workshop

Olivier Ferrante, president of the European Society of Air Safety Investigators (ESASI), provides an executive summary of the proceedings of the ESASI workshop "Safety Investigation Throughout the Aircraft Life Cycle—Design for Safety" held in Derby, UK, on May 22–23, 2019. The full report is available at https://www.esasi.eu/images/Derby2019/Derby_Workshop_Report.pdf.

The workshop was split into three sessions, each of which lasted half a day. The first two sessions focused on the current process of identifying safety issues and ensuring that lessons learned are fed back into the design specifications. The third session focused on the effectiveness of the interactions among the state investigators, regulators, manufacturers, and operators and questioned whether investigators had the necessary competencies to investigate design aspects.

The three sessions were

- Session 1. How can the investigation of design aspects be enhanced to improve safety throughout the life cycle of an aircraft?
- Session 2. How effective are safety recommendations and safety actions related to aircraft design?
- Session 3. How can we further improve the relationship among investigators from the safety investigation authorities (SIA), manufacturers, regulators, and operators?

Each session was led by a moderator who gave an introductory presentation setting out the main points, followed by four or five presenters who each briefly gave their perspective of the subject under discussion. The speakers represented SIAs in Europe and the United States, regulators, aircraft and engine manufacturers, operators, and training organizations. Delegates had been preassigned seating so that each table had representatives from across the aviation industry. Following the presentations, each table addressed several preset questions followed by a plenary discussion.

One of the main points from the workshop was that aviation safety is about managing risk; and while regulators, manufacturers, operators, and safety investigators are all focused on this aim, there can be, at times, conflicting priorities. The manufacturer and the European Union Aviation Safety Agency may need to address the continued airworthiness of the fleet and the confidence of the public, while the national regulator and the operator might have to address the operator's safety management system. At the same time, regulators, the manufacturer, and the operator will need to provide assistance and technical advice to the independent state accident/incident investigation authority. The timely exchange of information through complex communication channels can result in misunderstandings, with the risk of inadvertent disclosure of sensitive or proprietary information. The involvement of an SIA normally helps to balance the commercial pressure and provide a conduit for sharing information.

During the investigation, often only the original equipment manufacturer has the necessary expertise and test facilities to examine design-related contributory factors. This can sometimes pose a challenge to investigators in maintaining their independence, but it is normally balanced by a team approach composed of independent accredited representatives. The SIAs have a broader validation process and generally need time to review testing and work undertaken by the manufacturer. During this review, the SIAs may be seen as delaying the progress of the investigation and release of safety information.

Safety recommendations were a key part of the investigation process for effecting change and improving safety, provided they are issued in a timely manner. However, to be totally effective it is important that the SIA consults with the recipient of the safety recommendation during the drafting stage. The work of the European Network of Civil Aviation Safety Investigation Authorities (ENCASIA) was recognized in improving the quality of safety recommendations by publishing documents on guidance and best practice.

In addressing the question of how to improve relationships between the parties, it was agreed that this required trust, education, and commitment. Regular communication and collaboration on smaller events, such as serious incidents, allows the different parties to understand each other's processes and challenges. Investigators should develop a greater understanding of the design and continued airworthiness process and the development of complex aircraft systems. Manufacturers can facilitate this aim by arranging appropriate training and liaison visits for state investigators. Attendance at seminars and workshops and supporting major accident exercises were also considered essential preparation for the different parties to work together on a major safety investigation.

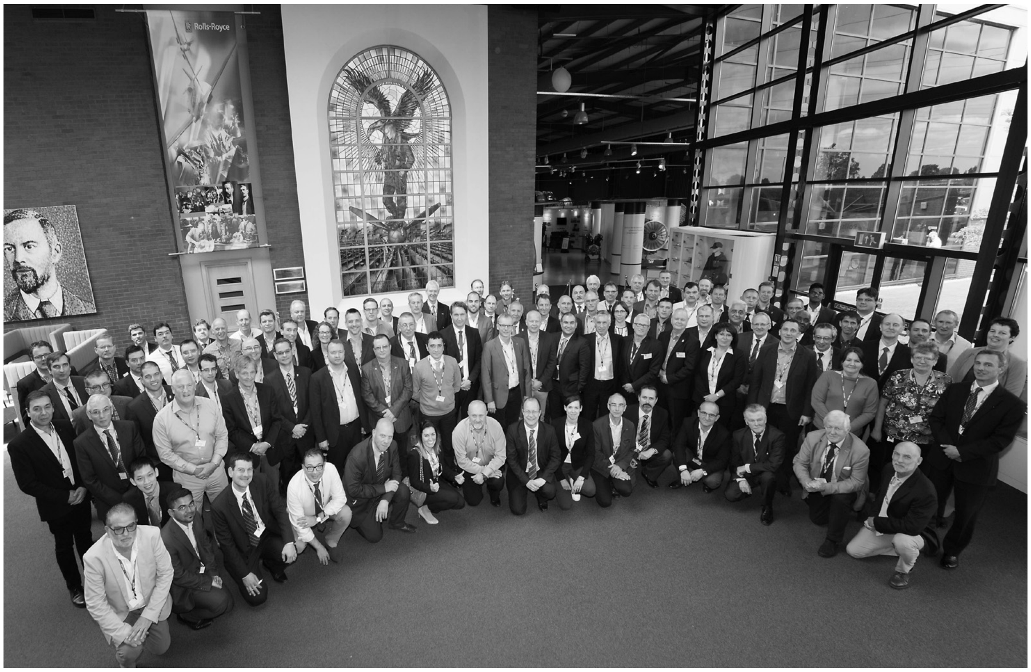
A summary of the points raised during the presentations and the discussion session form the body of this report. In the appendices, guidance material is added regarding the draft policy on safety recommendations developed by ENCASIA, the continued airworthiness process, and the classification of serious incidents (new Attachment C in International Civil Aviation Organization [ICAO] Annex 13).

A clear understanding of the continued airworthiness process is important as design and airworthiness questions are often intertwined. Please note we should use "continued airworthiness" when we refer to the fleet of a given aircraft type whereas "continuing airworthiness" should be used when we refer to an individual aircraft and the correct application of all airworthiness directives.

The continued airworthiness process is a process to collect information that may be relevant for safety on the products in service and to develop and implement corrective actions when this is needed to ensure that the intended level of safety is achieved or maintained. Continued airworthiness is actually ensured both by the manufacturer and the certification authority according to the division of tasks and principles established by regulations. Appendix 5 provides a summary of the European regulatory framework for type certificate holders and more details on the continued airworthiness process.

An outcome of the workshop was to ask for more guidance, notably through an update of ICAO Doc. 9756 Manual of Aircraft Accident and Incident Investigation that could include investigation techniques and concepts for highly integrated and modern onboard systems with intense usage of software.

To conclude, it is of utmost importance that the collaboration among industry, regulators, and SIAs under Annex 13 remains transparent to all parties and to the public. Society must understand, and have trust in, the safety investigation process. ◆



ESASI 2019 participants gather at the Rolls-Royce Learning and Development Center in Derby, UK.

ANZSASI 2020 Conference Rescheduled for November

The Australian and New Zealand Societies of Air Safety Investigators (ANZSASI) 2020 conference at the Novotel-Surfers Paradise, Queensland, Australia, has been rescheduled for Nov. 20–22, 2020, under the same terms and conditions as originally agreed upon. The Australian Society (ASASI), as this year's host, considered other options, including cancellation, but had a particularly good response to the original plan so "we believed it would be beneficial to reschedule.

"We chose the last date available for this year, prior to the normal pre-Christmas period. We are optimistic that Australia and New Zealand will be open for business again in time for us to make final plans for the conference. The hotel contract allows us to make a go/no-go decision at the beginning of October. However, we will keep you informed with progress in the planning and hope we will be able to make definite plans before this date.

"The speakers who had agreed to deliver presentations in May 2020 have all been contacted and offered the opportunity of presenting in November 2020.

"The information on the website has been updated accordingly. If you have already registered, your registration will automatically be transferred to the new dates unless you wish to cancel. A refund of your registration payment can be made by contacting the ASASI secretary. The hotel booking information will be updated to reflect the new dates.

"The seminar will follow our usual format with the Cabin Safety Working Group meeting on Friday, as well as the annual Australia-New Zealand golf championship. There may be changes to the format depending on the aviation industry situation at that time. A welcome reception will be held on Friday evening, followed by two full days of presentations on Saturday and Sunday and a dinner on Saturday night.

"The success of our annual ANZSASI seminar is always measured by the quality of the papers and associated presentations. The theme of the seminar is "Improving Safety," and a range of quality papers, collated by Geoff Dell, Rob Chopin, and Mike Walker, will address all aspects of transport safety, safety training and education, human factors, and technical developments.

"We will operate a paperless conference for ANZSASI 2020, using an event mobile app, which is now available. To select the app, go to eMobilise and enter ANZSASI2020 for the current information. All information will be updated once we get closer to the conference date and we have a draft program and speakers. We welcome any feedback on this initiative to be as environmentally friendly as possible." ◆

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A STUDENT'S PERSPECTIVE OF LIFE IN LOCKDOWN

By Nur Amalina Jumary, 2019 Kapustin Scholarship Recipient

When 2020 began, no one could have anticipated the words "unprecedented times" would become part of our vernacular in a few months. The COVID-19 pandemic has far-reaching impacts on our industry—with airlines relying on government aid to survive, flight and ground crews furloughed, and aircraft flown to their "graveyards" with no scheduled return flight. There was a time when the sky was brimming with life. Individuals moved across borders freely, and others ensured that people would get to their destinations safely. There are also others who were studying to build their careers in this industry but have graduated to an industry that has come to a standstill.

I am an aviation school graduate of the class of 2020. During my time in aviation school, I was in the company of passionate students who were equal parts determined and smart in knowing what they had to do in class and outside of class to land a job before graduation. A couple of my course mates were accepted into an airline's graduate program before their final term and were well on their way to starting their careers. Airlines worldwide have since furloughed many of their employees.

Like many aspiring pilots, a close friend worked part-time to fund her flying fees. When the Cadet Pilot Program in her home country accepted applicants, she applied and was invited to four separate and intensive interviews. She was accepted into the Cadet Pilot Program. Pilots worldwide have since gone from being in high demand to being grounded. Another course mate had received a job offer that required him to move to a different state. The same day he was scheduled to move, he was told the company had downsized to remain operational. This is what it is like graduating in a time of pandemic, and in a time when aviation is not enjoying its golden spell.

Since the beginning of 2020 and well before the pandemic, I became the deputy audit program manager at the same company that I began my aviation stint during my second semester in aviation school. I was lucky to have my internship evolve to a part-time position and then to a full-time employee of the company upon graduation.

Like other businesses, we adapt and respond to the changes as quickly and as best we can. Part of my responsibility is ensuring that our clients continue their safety procedures and practices even as their operating environment changes. Personally, I have found that the principles involved in doing my job remain true as I navigate my way around this pandemic.

If you are a fresh graduate like me or have a few more terms in aviation school, the following may benefit you, too.

Ensuring Oversight of Critical Areas

Being distant from your peers and lecturers may make you feel disconnected from the industry. Reading about the state of our industry in the news may discourage you from putting in the effort or keeping the passion alive. Consider the university being closed as a change in your operating environment.

Be present with all these changes and ensure that you have oversight of critical areas—your study plan and career goals. This is your time to pick up new skills. Get your hands dirty doing something technical or go online to learn a new subject on various free or inexpensive platforms. My pilot-to-be friend has since picked up her flying manual again to refresh her concepts after a few weeks of adjusting to this new life.

Staying the Course

If there is one thing any aviation student knows from paying attention in class is that the industry is cyclical. We have entered the industry during its lowest period. Planes will start flying again, and our industry will recover. Until then, it would be worthwhile to keep yourself updated regarding how the industry is responding and being shaped by this pandemic through subscribing to aviation websites and being active in aviation associations.

Perhaps worrying about an aviation career may not be at the top of your priorities now. When you are ready again, stay the course and review your critical areas. Afterall, success comes when your preparation today meets opportunities in the future. ◆

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