ALPA White Paper

A Gamble with Safety: Reduced-Crew Operations

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Foreward from ALPA President
Capt. Jason Ambrosi

For more than 15 years, the United States has enjoyed the safest period in aviation history. This didn't happen by chance or luck. It was the result of collaboration and the presence of at least two experienced, well-trained, and rested pilots on the flight deck at all times.

Today, ALPA finds itself once again in the critically important role of championing safety over aggressive corporate interests that could undermine our nation's successful aviation story. Our industry can either choose to continue on a proven path that builds on the safety successes of our past—centered around human input and our superior capability for informed decision-making—or veer off course and allow corporate interests to place profit ahead of the public interest and safety by attempting to remove pilots from the flight deck.

Since its founding in 1931, the Air Line Pilots Association, Int'l has been committed to advancing the cause of safety, and as technology advances in our industry, pilots remain the ultimate force for safety in the skies. This white paper reinforces the well-established fact that pilots cannot be replaced through advances in technology—they are the most important safety feature on every airline flight, regardless of whether it is carrying passengers or cargo.

Day in and day out, it is the quick actions, critical decision-making skills, and experience of airline pilots that perpetuates and causes safety in aviation. Analysis of line operational safety audit data indicates that pilots intervene to manage aircraft malfunctions on 20 percent of normal flights, yet because of the decisive interventions of airline pilots, those malfunctions rarely result in anything more than a maintenance report.

The impact of human intervention on safe outcomes in aviation is clear. When pilots intervene to address an in-flight malfunction, an estimated 99.9994 percent of malfunctions do not result in an accident. Because our understanding of how humans react and recover from issues that occur in flight is based on reports of intervention or failures, and pilots are frequently able to completely remedy an issue in flight, the rate of human intervention where the outcome is not an accident is under-reported. Of the estimated 50 million events where the outcome did not result in an accident due to human intervention, a team of at least two airline pilots on the flight deck were the reason.

Despite this, at least one major airplane manufacturer is actively taking steps to reduce the crew complement on commercial airliners and, in some instances, government regulators are greasing the skids for them. The facts presented in this white paper clearly exhibit that there is no replacement for the safety benefits of having at least two pilots on the flight deck at all times. Any programs designed to reduce the number of crewmembers on the flight deck would put airline operations at risk and present a large step backward in our continual effort to improve safety performance.

On the flight deck, pilots work together, observe each other, and communicate nonverbally, creating a smooth workflow in an emergency where they simultaneously fly the plane, attempt to resolve issues or prevent them from escalating, and create safe outcomes. Pilots are the core safety feature in aviation.

Through intensive training, extensive flight experience, human senses, and uniquely human critical thinking and decision-making skills, pilots are ready to engage and create safe outcomes when something goes wrong in flight. The research identified in this white paper underscores the danger that a reduction in the number of pilots on the flight deck would measurably limit the ability to create safe outcomes.

Attempts to remove pilots from the flight deck represent the most critical threat to safety and security that our industry faces, and we owe it to the passengers, cargo shippers, and communities under our wings who depend on the strong safety record built by pilots to stop this gamble with safety.

Executive Summary

In 2019, ALPA published a white paper titled "The Dangers of Single-Pilot Operations." It found that despite interest in removing a pilot from the flight deck, the safety risks far outweigh any potential benefits. Commercial aviation is the safest form of transportation in the world due in large part to the skill and experience of well-trained pilots who are ready to respond to any situation. This high level of safety has been supported by the requirement for two qualified pilots on the flight deck during both passenger and cargo flights, with potentially more for long flights requiring multiple crewmembers. While advances in technology have brought automation to the flight deck, pilots remain responsible for the safety of the aircraft and its occupants.

ALPA is providing an update to that 2019 paper to ensure that the public remains informed about the continually evolving discussions related to single-pilot operations. ALPA has conducted a review of new research, policy changes, and technological developments since 2019 to inform its continued engagement on this issue. While some would argue that progress has been made toward making single-pilot operations technically feasible, most would find that technical progress does not substitute for the well-established safety requirement for two qualified pilots to be present on the flight deck at all times. Regulators should continue to focus on improving this standard, rather than changing it.

Aviation Safety: Research continues to show that single-pilot operations carry significant safety risks and are an unsubstantiated alternative for two qualified pilots on the flight deck. Having only a single pilot would increase the workload on that pilot, thereby increasing the risk of mistakes in both "nominal" operations and especially during high-workload phases such as takeoff, approach, and landing. Moreover, in cases of medical emergency or pilot incapacitation, a second pilot is crucial to ensure the safety of the flight.

Technical Barriers: While recent years have seen continued progress in several technological areas, this does not change the fundamental necessity for two pilots on the flight deck. There remains critical technology gaps without any viable or researched human equivalency, and unresolved but critically important questions about communications reliability and cybersecurity. Remote pilot assistance systems will not be a sufficient substitute for a second pilot, and presents a range of critical safety, coordination, and communication issues that are so far unresearched.

Regulation and Policy: Regulatory frameworks in the United States are purposefully designed to reinforce and support the well-proven two-pilot paradigm which has allowed the United States to be a global leader in aviation safety. U.S. regulators are rightly focusing on improvements to safety, training, and certification, which have clear, demonstrated benefits. Shifting focus toward single-pilot operations should not come at the expense of decades worth of hard-won safety improvements, especially given the immature nature of the technology at issue. Public statements at the 2023 Air Safety Forum by Andy Cook, Transport Canada associate director general, Civil Aviation, made it clear that Canada was not entertaining any changes in the two-pilot paradigm at that time.

Advanced Air Mobility: Developments in adjacent aviation sectors such as advanced air mobility (AAM), may soon be a driver for automation-related technologies and operations, and an attractive proving ground to influence single-pilot operations in the airline operating environment. Air taxis and electric vertical takeoff and landing (eVTOL) platforms in development aim to operate with a single pilot at their onset, with some planning to remove the pilot completely in the future. Clearly, eVTOL aircraft will incorporate increasing amounts of autonomy. However, their progress in technology advancement is facing regulatory, safety, and economic factors that are thus far unproven, and sufficiently different from those found in traditional aviation such that changes in one domain cannot and should not be assumed to mean the immediate applicability to the other.

Throughout the discussion contained in this white paper, there remains this unequivocal fact—having two pilots, always on the flight deck of an aircraft, is the safest and most secure way to conduct airline operations.

Section 1: Aviation Safety

Despite the fact that there is an ever-present influx of challenges, commercial air travel is the safest mode of transportation. The remarkable safety record of the airline industry hinges on the requirement for two pilots on the flight deck. Single-pilot operations (SPO), by definition, reduces this level of safety and security. Current and projected automated system technologies do not represent an acceptable solution or safety equivalence to the two-pilot model. Having two pilots on the flight deck is a proven key to the safety and security of commercial air transportation. In addressing specific aspects like redundancy, over-reliance on automation, security, and limitations of automatic systems, the conclusion is easy: SPO is not a risk worth taking.

Commercial Aviation Remains Safest Mode of Transportation

When compared to all other modes of point-to-point transportation, airline travel is the safest and most secure option. Worldwide in 2022, 31 million flights carried 3.2 billion passengers between airports. Seven fatal accidents were recorded, one in North America, resulting in 160 fatalities for scheduled airlines.[1] Even when comparing worldwide commercial aviation accident rates to U.S. statistics for automobiles (0.56%), trains (0.3%), and buses (0.02%), commercial air travel is by far the safest mode of transportation.[2]

Our nation's exemplary safety record is maintained because of industry adherence to U.S. federal aviation regulations, meticulous aircraft manufacturing and maintenance standards, enforcement of strict security protocols, and, most importantly, the requirement for a minimum of two highly trained pilots on the flight deck.

The level of safety performance has even been maintained in the face of turbulent disruptions to society and aviation. The COVID-19 pandemic led to an unprecedented drop in the number of airline passengers. In 2020, only 1.8 billion passengers flew on scheduled airlines, a drop of 60% from the previous year, when 4.8 billion passengers took to the air aboard 38 million flights.[3] Notably, as the airline industry resumed flights following easing of COVID-19 restrictions, it did so in a manner that maintained the high level of safety and security that existed prior to the pandemic.

Reduced-Crew Operations: Passenger and Cargo Airlines Are Investigating

Today, there are always two pilots on the flight deck of every commercial passenger and cargo airline flight. Certain flights considered to be "long haul flights" are supplemented with additional pilots to rotate duty shifts, which ensures that the pilots on the flight deck remain free of fatigue. The off-duty pilots are given time to rest in a rest facility onboard the aircraft. Therefore, two pilots remain on the flight deck at all times.

Globally, some airlines and aircraft manufacturers continue to look for ways to reduce the number of pilots needed to safely conduct a flight. Reducing the crew to a single pilot is apparently an extremely lucrative

1 ICAO *2023 Safety Report* www.icao.int/safety/Documents/ICAO_SR_2023_20230823.pdf, accessed June 3, 2024.
2 https://injuryfacts.nsc.org/home-and-community/safety-topics/deaths-by-transportation-mode, accessed November 15, 2022.
3 ICAO *2021 Safety Report*, www.icao.int/safety/Documents/ICAO%20Safety%20Report%202021%20Edition.pdf (accessed November 15, 2022).

financial incentive for the airlines. New terms such as "single pilot operations" or SPO, and extended minimum crew operations (eMCO) have been introduced into the aviation industry over the last several years. These initiatives attempt to create an equivalency between automated systems and their human operators, advocating that the former can replace the latter. RCO encompasses both eMCO and SPO (RCO = eMCO/SPO), and both versions of RCO attempt to set a new precedent for highly automated reduced or no-pilot operations.

Based on analysis by many different aviation safety experts around the world, any form of RCO, including SPO and eMCO, reduces safety and security levels to an unacceptable level. The use of RCO in airline operations reintroduces holes in the safety net that the global airline industry has worked very hard to close. Highly automated systems do not represent a viable solution to compensate for a missing or intentionally removed pilot. Two pilots on the flight deck are key to the safety and security of commercial air transportation.

Extended Minimum Crew Operations

Airbus has announced a new approach known as extended minimum crew operations (eMCO), which is proposed as a way to optimize crew efficiency and increase air carriers' profitability. The cornerstone of this concept is a protocol allowing one pilot to leave the flight deck during the cruise phase of flight for an extended rest period, and no other pilot onboard to replace the resting pilot. This strategy is intended to stretch the boundaries of maximum pilot flight-time limitations by deliberately extending pilot rest intervals.

However, from a safety perspective, this proposal raises significant concerns. By reducing the flight deck crew to a single pilot during the cruise phase, the eMCO model introduces potential vulnerabilities that could compromise flight safety and security. Even though the cruise phase is typically less demanding, unexpected situations can and do arise that require immediate decision-making and action, which is best and most safely handled by a two-pilot crew.

From a regulatory perspective, the Federal Aviation Administration (FAA) and other global aviation regulators, such as the European Union Aviation Safety Agency (EASA), limit duty time and mandate crew rest periods to manage fatigue risk. This requirement is defined in the Federal Aviation Regulation (FAR) Part 117 and Part 121 in the United States and in EASA Flight-Time Limitation (EASA FTL) rules (established by EU Regulation 83/2014, which is codified in Part-ORO [Organisation Requirements for Air Operations] of Annex III to Commission Regulation [EU] No. 965/2012).

The aviation industry's steadfast commitment to safety must not be undermined by any proposals that may escalate risk. As it currently stands, the eMCO model appears to be a risky compromise, failing to meet the industry's stringent flight-safety standards and the trust of the traveling public. The safety of passengers and crew should always take precedence over economic considerations, thereby rendering this model unsuitable in its present form.

In practice, eMCO is a single-pilot operation. eMCO would simply add risk in exchange for an economic benefit. eMCO concepts would still carry the risk of pilot incapacitation, and further eliminates options for quickly handling incidents in the cabin. Even routine considerations around the eMCO proposal raise serious safety and operational concerns. Imagine, for instance, a scenario where a single pilot must use the lavatory. This would result in an uncrewed flight deck, presenting a significant risk to the aircraft and everyone on board in the event of an emergency or onboard disruption.

Moreover, even if the lone pilot remains on the flight deck, the workload could significantly escalate, potentially increasing fatigue levels and reducing situational awareness, which are crucial flight safety components.

Finally, proposed eMCO models could set a precedent for adopting expanded reduced crew operations (RCO). The progression of RCO concepts in long-haul passenger and cargo flights could also set a precedent for single-pilot operations (SPO) in commercial transport aviation operations involving passengers and/or cargo carriage. This completely undermines the safety precedent that has been set in the aviation industry.

In summary, SPO and other RCO concepts like eMCO reduce safety and security levels. Highly automated systems do not represent an acceptable solution to this shortfall. Two pilots on the flight deck are key to the safety and security of commercial airline transportation.

Two Pilots on the Flight Deck Key to Maintaining High Level of Safety and Security

Even with improvements in aircraft reliability and advances in automatic systems, multiple pilots are necessary to share the considerable workload required to fly an airliner. Two pilots on the flight deck ensure redundancy; they monitor the health of each other and the aircraft, maintain situational awareness of aircraft systems and the external environment, and provide a critical layer of security.

Pilots have the training, skill, and experience necessary to handle almost any situation, be it system malfunction, inclement weather, or air-traffic congestion. Pilots are actively in control of every commercial airline passenger and cargo aircraft from departure to arrival. The notion that computers do most of the flying in modern commercial aircraft, even during takeoff and landing, is false. During normal operations, one pilot ("pilot flying") is responsible for flying the airplane, while the other pilot ("pilot monitoring") is responsible for monitoring the pilot flying's actions, the flight path of the aircraft, the aircraft and systems states, as well as support functions including communications with air traffic control and ensuring checklist completion.

This configuration is necessary for safe and secure operations of commercial airline transportation because it provides critical redundancy in the form of workload sharing, continued control of the aircraft in the event of pilot incapacitation, and application of security protocols. This redundancy depends on maintaining a high level of proficiency in multiple skills, and that high level of proficiency is achieved through flight experience and a robust training program focused on proper crew resource management, appropriate use of automatic systems, and security. SPO effectively removes this redundancy, replacing one pilot with either automatic systems or a ground-based pilot. Both approaches introduce an entirely new and greatly expanded set of risks that further compromises safety and security.

A Two-Pilot Flight Crew Improves Learning and Helps Prevent Accidents

Typically, the pilot flying and pilot monitoring duties alternate between the captain and first officer on each subsequent flight leg, where the captain may act as the pilot monitoring and the first officer acts as the pilot flying, then on the next flight leg, those roles will swap to ensure that each pilot keeps their skills honed. Additionally, there is no safety reporting system that records how often a pilot intervenes with automation during flight, and pilot interventions to correct automation are not reported since these are considered routine actions by the pilot. Many times, through each flight, pilots intervene because the automation is not effectively or efficiently accomplishing an intended task, or there is a required intervention needed due to ATC. There also could be an inflight emergency, which could involve a system malfunction or onboard event that needs to be addressed immediately.

Cross-checking and error detection: RCO would eliminate the possibility of cross-checking between pilots, which can lead to more risks and errors. Error detection from cross-checking is crucial for safety as it can prevent accidents.[4] Furthermore, continuous monitoring allows the crew to quickly and better react to aircraft system failures.[5] Two pilots, therefore, are better than a single crewmember to detect errors. With only one pilot on the flight deck, feedback and opportunities for cross-checking, communication, and coordination are eliminated, and errors are very likely to increase.

4 Reason, James. "Human Error." *Cambridge University Press.* 1990. doi:10.1017/CBO9781139062367

5 Kanki, Barbara G., Robert L. Helmreich, and José Anca. "Crew Resource Management." *Academic Press.* 2010.

Redundancy: Why Two Pilots Are Better Than One

Years of technical studies and pilot experience have consistently demonstrated that having two pilots on the flight deck spreads the workload, allows more effective mitigation of medical or behavioral events, and doubles the skill and experience that can be brought to bear on rapidly evolving conditions caused by in-flight emergencies and compromised security conditions.

Workload Sharing

Workload sharing is especially critical during in-flight emergencies where rapidly unfolding events benefit from the combined experience of two qualified pilots. A NASA/FAA study found that having two pilots on the flight deck during emergency situations is critical and that RCO/SPO poses an unacceptable safety risk.

> "The data supports the criticality of the human's role and the adaptability of human pilots/flight crew that is instrumental in overcoming non-normal conditions and in completing safe recoveries, even in SPO. The pilots were able to workload-shed tasks and duties, enlist help from ATC or their airline dispatch center, and perform actions and make the proper decisions in enough time to safely complete the flight within acceptable flight performance limits. The data also indicate, however, that single pilot operations are not nominally acceptable due to the significant task demands and workload. The pilots could overcome the circumstances presented, but rated the workload, safety, and acceptability as being unacceptable in an emergency situation. There were notable flight performance decrements during SPO compared to two-crew operations that suggest unacceptable, reduced safety margins."[6]

The presence of two pilots on the flight deck serves as a crucial safeguard for identifying and rectifying emergencies arising from environmental factors, human error, or malfunctions. This relies not only on a well-trained, well-rested, two-piloted crew, but also on their intuition and instinct, which highly automated systems cannot take into account. Incorporating these human qualities and strengths into automated systems is not feasible.

Historical Events: Where Two Pilots Averted Catastrophic Loss

Statistics are not gathered for accidents or incidents averted by pilot action, but there have been several examples where emergencies were handled by two pilots to avert catastrophic loss of the aircraft and passengers. The events below are just a few examples of where a two or more pilot flight deck was essential in preventing the loss of life, among them:

- **United Airlines Flight 232 (July 1989)—**A DC-10 airliner flying from Denver, Colo., to Chicago, Ill., experienced catastrophic failure of the tail-mounted engine during the cruise phase of the flight. The failure produced high-velocity debris that severed hydraulic lines necessary to manipulate flight-control surfaces. The two pilots, the flight engineer, and a training check airman worked together to identify a solution to the problem, which was to modulate thrust of the remaining two engines to provide some degree of flight control. This effort led to a crash landing at the airport in Sioux City, Iowa, saving 184 passengers and crew but resulting in loss of 112 lives. Investigators subsequently commended the flight crew's performance for greatly exceeding expectations and contributing to the creation of crew resource management (CRM), which encourages collaboration and became a standard in the industry thereafter.[7] This outcome was only possible with the coordination of multiple crewmembers and a creative solution provided by a qualified trainer who happened to be aboard. A single pilot would have been unlikely to produce a similar result.
- **British Airways Flight 5390 (June 1990)—**A BAC One-Eleven Series 528FL flying from Birmingham, England, to Malaga, Spain, experienced an explosive decompression about 13 minutes after takeoff while climbing through 17,300 feet. The captain was partially sucked out of the windscreen. The first officer re-engaged the autopilot that became disengaged by the displacement of the flight controls

6 NASA NTRS. 2017. https://ntrs.nasa.gov/citations/20170009542

7 See also NTSB Accident Report: United Airlines Flight 232 McDonnell Douglas DC-10-10 Sioux Gateway Airport, Sioux City, Iowa, July 19, 1989, www.ntsb.gov/investigations/AccidentReports/Reports/AAR-90-06.pdf (accessed November 17, 2022).

during the captain's partial egress. the first officer continued to fly the aircraft while the #3 flight attendant was holding on to the captain. The #2 flight attendant entered the flight deck and started holding on to the captain's ankles, who had slipped further out of the flight deck window. The flight landed about 22 minutes after the explosive decompression in Southampton, England. The captain suffered broken bones, bruising, frostbite, and shock, but survived the event. [8]

- **Air Transat Flight 236 (August 2001)–**Four hours into a flight from Halifax, Nova Scotia, to Lisbon, Portugal, the aircraft began leaking fuel through a fractured fuel line, a situation reflected as abnormal oil and pressure readings but not initially seen as an emergency. More than an hour after the leak started, both engines shut down and the aircraft lost electrical power. The auxiliary ram air turbine deployed as designed, providing power for flight instrumentation and control-surface hydraulics. Both pilots worked together to glide the aircraft over open ocean to a safe landing at Lajes Air Force Base on Terceira Island, Azores. A single pilot would have been unable to assess the situation while calculating glide-performance data in this scenario.[9]
- **US Airways Flight 1549 (January 2009)–**Immediately after takeoff from LaGuardia Airport in New York enroute to Charlotte, N.C., the Airbus A320 struck a flock of birds, resulting in damage to both engines and total loss of thrust. Both pilots managed the situation by requesting an emergency landing at a nearby field, but recognizing this was not possible, the captain elected to ditch into the Hudson River. Deviating from the checklist for such an emergency due in part to the very low altitude, the pilots activated auxiliary power to provide instrument power. These actions saved all 155 passengers and crew, an event widely celebrated in the media as an example of exemplary pilot skill and experience during an emergency.[10] Reflecting later, Capt. Chesley Sullenberger recounted, "Well, the crew had their jobs to do and the first officer, Jeff Skiles, certainly did, and he was my partner throughout this whole episode. I couldn't have done it without him. In fact, had he been a lot less experienced, had he not had the 20,000 hours of flying time that he has like I do, had he not been a captain before and understood how to collaborate with me wordlessly by knowing his roles and responsibilities so well, because we didn't have time in those 208 seconds to have a conversation about what had happened, I didn't have time to direct his reaction."[11] This outcome highlights the importance of flight deck resource management between two highly skilled pilots, both depending on each other to address the inflight emergency.

- **Southwest Airlines Flight 1380 (April 2018)–**Just before reaching cruising altitude after taking off from LaGuardia Airport, N.Y., the two-engine Boeing 737 experienced an engine failure, resulting in high-velocity debris striking the cabin and causing rapid decompression. Despite aircraft-handling difficulties, the pilots conducted a safe landing with everyone surviving except one passenger, who was injured due to debris that had penetrated the fuselage. The captain described the coordination with the first officer in safely landing the aircraft: "We kind of just split the flight deck and I did flying and some of the outside talking and he took care of everything else."[12] This represents another example of how two pilots depended on each other to manage an inflight emergency.

8 https://assets.publishing.service.gov.uk/media/5422faa7e5274a131400078d/1-1992_G-BJRT.pdf
9 2019 ALPA White Paper
10 Ibid.
11 Kruse, Kevin, "Stick The Landing: An Interview With Sully Sullenberger," *Forbes*, July 21, 2017, www.forbes.com/sites/kevinkruse/2017/07/21/stick-the-landing-an-interview-with-sully-sullenberger/?sh=6a5677657106 (accessed November 17, 2022).
12 Reed, Ted, "Southwest 1380 Landing Proves Study Of Single Pilot Cargo Aircraft Is 'Silly,' Pilot Leader Says," *Forbes*, May 11, 2018, https://www.forbes.com/sites/tedreed/2018/05/11/study-of-single-pilot-cargo-aircraft-is-silly-and-southwest-incident-proves-it-pilot-leader-says/?sh=5621eb154412 (accessed November 17, 2022).

- **Qantas Flight 144 (January 2023)–**The pilots encountered an engine malfunction emergency from Auckland to Sydney. The pilots issued a mayday call and immediately worked to navigate the plane to safety at Kingsford Smith Airport. The event exemplifies how two well-trained pilots can effectively share workloads during an emergency. As a result, the passengers praised the staff for their ability to remain "calm and professional."[13] The chances are very low that a single pilot could appropriately juggle multiple tasks in an emergency while controlling the aircraft, communicating with Air Traffic Control, communicating with the cabin crew, liaising with the airline, and simultaneously calming passengers.

- **Southwest Flight 6013 (March 2023)–**The flight took off from Las Vegas destined for Columbus, Ohio, and one of the pilots experienced a medical emergency mid-flight. An off-duty pilot stepped in to assist the remaining pilot and helped the plane safely return to Las Vegas. This incident showed that at least two pilots are required to share workloads during an emergency on the flight deck.[14]

SPO will impose an increased workload and greater stress on the remaining pilot, particularly during the riskiest phases of flight, takeoff and especially landing.[15] Off-nominal events during flight include adverse weather conditions, turbulence, aircraft malfunctions, and flight deviations, events that pilots routinely encounter and are best equipped to address. In rare instances, these and other off-nominal events can degrade into inflight emergencies. A single pilot would be at high risk of being overwhelmed during these events. Further, airline administrative processes, especially as they involve flight operations, have become increasingly automated as airlines look to trim staff to save money and increase efficiency.[16] This has added dispatch and inflight administrative responsibilities to pilots, increasing the workload even further by adding additional documentation and calculations. Factoring in these recent developments, the additional pilot workload stemming from SPO has the potential to cause even greater risks.[17]

Qualified Backup in the Event of Pilot Incapacitation

Having two pilots on the flight deck increases the confidence of everyone onboard the aircraft. Part of this confidence is knowing that if one pilot becomes incapacitated, the other can assume control immediately and land the aircraft safely. Even though some airplanes have automatic systems that, with the assistance of a pilot, can conduct the landing phase of flight at a few runways at certain airports, two pilots are better able to handle this critical phase of flight, sharing responsibilities and reducing workload stress when the aircraft is in a relatively vulnerable state.[18]

Pilot incapacitation does occur and presents a significant hurdle for SPO. Having two pilots on the flight deck provides a critical redundancy should one become incapacitated due to adverse medical or behavioral conditions. Several studies have been initiated to address this potential shortfall, with one confirming that "pilot

13 Evans, David. "We need two pilots at the pointy end." *The Sydney Morning Herald.* 2023. www.smh.com.au/national/we-need-two-pilots-at-the-pointy-end-the-qantas-mayday-shows-us-why-20230118-p5cdlh.html

14 "Off-duty pilot on Southwest flight steps in after pilot's medical emergency." *KSL News Radio.* 2023. https://kslnewsradio.com/1995310/off-duty-pilot-on-southwest-flight-steps-in-to-help-after-pilot-suffers-in-flight-medical-emergency

15 Thomas, Geoffrey, "Landing the Most Dangerous Phase of Flight," *AirlineRatings.com* www.airlineratings.com/news/passenger-news/landing-dangerous-phase-flight (accessed November 15, 2022).

16 Whitley, Angus, "Airlines Push for Lone Pilot Flights to Cut Costs Despite Safety Fears." Bloomberg www.bloomberg.com/news/articles/2022-11-20/lone-pilots-flying-passenger-planes-solo-is-prospect-for-near-future

17 European Cockpit Association Position Paper, "The Human and the concepts of Extended Minimum Crew Operations (eMCO) and Single Pilot Operations (SiPO)" www.eurocockpit.be/sites/default/files/2021-07/eMCO_SiPO_PP_21_0719_F_1.pdf (accessed November 15, 2022).

18 https://flygv.com/blog/the-importance-and-benefits-of-utilizing-dual-pilot-operations (accessed November 15, 2022).

incapacitation is already handled very well in practice with respect to the regulations and procedures in current usage."[19] At least one study investigating how this might be handled in a SPO configuration confirmed that two pilots on the flight deck "offers protection against human errors and cases of pilot incapacitation" and that "solutions for remote or automated piloting of the aircraft in cases of pilot incapacitation must be found."[20]

Remote Pilot

Remote pilot assistance has been proposed as an option for SPO to mitigate excess workload and the potential for a single pilot to become incapacitated. This scenario features a ground-based pilot who can assist an onboard pilot and take control of the aircraft if necessary.[21] However, this arrangement presents new vulnerabilities that compromise safety and security. Among them are loss of nonverbal communications on the flight deck and potential communication disruptions between the flight deck and air traffic control. Even the communications latency between the remote pilot and the pilot onboard the aircraft pose additional complications.

Many configurations featuring remote pilot assistance have been explored; one study analyzed these configurations and found that a single pilot can rapidly become overloaded if the information and data exchange is not mediated by ground-based assistance.[22] That ground-based assistance is itself vulnerable, as it is susceptible to degradation and interference, either by natural or artificial means.[23] The ground pilot would also lack any sensory input in terms of how the aircraft feels in flight. The potential for cyberattacks will be covered in greater detail in the technical barriers section. Reduced resiliency of such a critical data link for off-nominal conditions represents an unacceptable safety risk.

Application of Security Protocols

Airlines have procedures to deal with in-flight disturbances, which rely on two pilots working together. In addition, U.S. regulations require that two individuals always be on the flight deck and the use of physical barriers like a reinforced and locked flight deck compartment door.[24] SPO removes a level of security redundancy, potentially requiring a single pilot to shift attention away from directly managing a flight. One pilot alone on the flight deck is also a significant degradation in the ability for pilots to fend off an attacker if they are able to somehow enter the flight deck.

19 Schmid, D., Vollrath, M., & Stanton, N. A. (2018). The System Theoretic Accident Modelling and Process (STAMP) of medical pilot knock-out events: Pilot incapacitation and homicide-suicide. Safety Science, 110, 58–71. doi:10.1016/j.ssci.2018.07.015.

20 Vu, K.-P. L., Lachter, J., Battiste, V., & Strybel, T. (2018). Single pilot operations in domestic commercial aviation. Human Factors, 60(6), 755–762. doi:10.1177/0018720818791372 https://journals.sagepub.com/doi/full/10.1177/0018720818791372 (accessed November 16, 2022).

21 Martins, Ana et al, "Towards single pilot operations: A conceptual framework to manage in-flight incapacitation," 11th SESAR Innovation Days (December 2021).

22 Harris, D. (2018), "Network re-analysis of Boeing 737 accident at Kegworth using different potential crewing configurations for a single pilot commercial aircraft," In D. Harris (Ed.), *Engineering psychology and cognitive ergonomics* (pp. 572–582). Cham, Switzerland: Springer.

23 Schmid, D., & Korn, B. (2018), "The operational issue of an airliner's reduced-crew caused by data-link break-up to remote support," *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 62, 71–75. doi:10.1177/1541931218621016.

24 Schmid, D., Vollrath, M., & Stanton, N. A. (2018). The System Theoretic Accident Modelling and Process (STAMP) of medical pilot knock-out events: Pilot incapacitation and homicide-suicide. Safety Science, 110, 58–71. doi:10.1016/j.ssci.2018.07.015.

Section 2: Technical Barriers

Technological progress in automation has been made since ALPA's first paper in 2019, however, several key gaps remain regarding the technical ability to automate key aviation functions. In particular, technologies that contribute to aircraft autonomy and integrated vehicle health management still face challenges related to maturity, cost of implementation, and trust between human operators and autonomous systems. And even if progress is made in these areas, cybersecurity will continue to be a major concern whenever computer systems replace human intervention. Even proponents of single-pilot operations note that more research will be needed for implementation and the U.S. government's primary civil aviation research agency, NASA's Aeronautics Mission Research Directorate, has a full research agenda which does not include a push toward single-pilot operations.[25] Significant investments in single-pilot operations research could crowd out other priorities, such as experiments with aircraft designs, electric propulsion, and safety improvements (such as runway accident prevention). This section will discuss ongoing barriers toward the widespread implementation of autonomous decision-making and structural health monitoring that must be addressed for single-pilot operations.

Autonomous Decision-Making

One of the fundamental technology barriers to single-pilot operations is the development and implementation of autonomous decision-making. The complexity of this technology presents multidisciplinary challenges that span fields of engineering, policy, cybersecurity, and human factors. Autonomous decision-making relies on a tremendous amount of data regarding the aircraft state, diagnostic and prognostic trends, and operational environment. Due to the interconnected nature of autonomy within the national airspace system, considerations must be given to the validation of autonomous software, cybersecurity, and operator trust in AI.

Autonomous Decision-Making: Verifying and Validating Adaptable Systems

Autonomy is defined by NASA as "the ability of a system to achieve goals while operating independently of external control."[26] To act independently, an autonomous system relies on knowledge acquired through the collection and interpretation of sensed states. These systems often rely on AI or other adaptive software to learn from data collected in operational or simulated experiences to improve their system response over time.

Verifying and validating adaptive learning systems is difficult and presents challenges for the technology maturation process. If an autonomous system uses knowledge acquired during operation to improve over time, its behavior in its operational environment may not be the same as it was during ground testing. New approaches in verification and validation are required to demonstrate consistent, safe behavior in autonomous systems. These maturation challenges, coupled with public mistrust of autonomy, can lead to slow adoption of these systems in transportation.

25 NASA Aeronautics Strategic Implementation Plan 2019 Update, NASA ARMD, www.nasa.gov/sites/default/files/atoms/files/sip-2019-v7-web.pdf

26 T. Fong, "Autonomous Systems NASA Capability Overview," p. 26, 2018

Autonomous Decision-Making: Cybersecurity Concerns

Autonomous decision-making not only relies on information collected about the aircraft state, but also on additional inputs supplied by the broader air traffic management system. Using increasingly complex, interconnected networks in air- and ground-based systems provides opportunities for sophisticated cyber- and cyber-physical attacks. Vulnerability to these attacks can arise from increasing reliance of aircraft systems on sensors, network communication, and physical ground elements, as they provide additional attack surfaces for cyber threats.

Autonomous Decision-Making: Human-Autonomy Interaction

Autonomous decision making requires complex interactions between all involved systems and actors in operational environments. This may include human-autonomy teaming, in which human and autonomous agents work in tandem to perform a task.

Currently, autonomous systems cannot monitor and interact with a pilot as efficiently as another human pilot. Nonverbal cues, trust, and inference are all aspects of interpersonal communication that cannot yet be replicated in autonomous systems. Many autonomous systems, particularly those that rely on artificial intelligence, can be particularly opaque to human operators and can result in a lack of trust between the operator and the system. In these scenarios, it will not matter how capable the autonomous system is if the human pilot, remote operator, or ATM overseers do not trust the system.

To date, technology advancement has outpaced research on human-autonomy teaming and trust. While there have been great strides in specific research related to automated tasks such as cruise control or autopilot functions, fewer studies focus on AI-based autonomy that may adapt or change behavior over time.[27] One way to increase trust in human-machine systems is through explainable AI. Oftentimes, the inner workings of an AI system can be a black box and its internal logic is not clear to the end users, reducing understanding and trust in these systems, especially in times of emergency and increased stress. Explainable AI systems is an ongoing field of research that aims to develop best practices and methods for increasing clarity and trust between human operators and AI systems.

Broadly explainable, AI can be considered across three main aspects: transparency, interpretability, and explainability. Altogether, these aspects span the model, design, algorithm, and inputs/outputs of the system.[28] Explainability is especially critical in high-risk and emergency scenarios. Studies show that when working with autonomous flight planners with low levels of transparency, pilots were less likely to trust the system's recommendations when the risk was high.[29] This can result in the need for additional verification and downtime in emergencies. These unanswered questions pose risks if more decision-making is shifted to automated systems.

An article written by William Kaliardos, from the FAA Office of NextGen, goes into great detail about the potential risks associated with automation.

> "Even when specific cases of automation have been demonstrated, safety-critical applications present additional challenges, especially for very low-probability events. Furthermore, some events are a type called "unknown unknowns". That is, we can assume there are events that could occur during operation, but that we do not know specifically what they are. Consideration of unknown unknown operational events are safety and validation challenges, and an important aspect of resiliency. They are even more important as the functions being automated encroach on what have traditionally been performed by humans, partly due to the belief that humans can often better adapt to situations that were not explicitly trained, nor explicitly considered during design. Although that belief may be shifting with ML, for example, it remains that unknown unknowns are an important aspect of safety, and further limit our ability to understand automation's capabilities.

27 Chahal, Margarita Konaev and Husanjot. "Building Trust in Human-Machine Teams." Brookings, 18 Feb. 2021, www.brookings.edu/techstream/building-trust-in-human-machine-teams.

28 S. Sutthithatip, S. Perinpanayagam, S. Aslam and A. Wileman, "Explainable AI in Aerospace for Enhanced System Performance," 2021 IEEE/AIAA 40th Digital Avionics Systems Conference (DASC), 2021, pp. 1-7, doi: 10.1109/DASC52595.2021.9594488.

29 G. Sadler et al., "Effects of transparency on pilot trust and agreement in the autonomous constrained flight planner," 2016 IEEE/AIAA 35th Digital Avionics Systems Conference (DASC), 2016, pp. 1-9, doi: 10.1109/DASC.2016.7777998.

"One well-known problem in the use of automation categories is the issue of insufficient functional detail. For example, one might describe an entire aircraft as having a certain degree of automation, without any description of the aircraft functions. While this is theoretically possible (perhaps in fully automated or fully manual aircraft), it implies that all the functions on the aircraft are automated similarly. For reasonably complex systems, and in the context of the human-centered aviation system that exists today, the myriad of functions combined with the myriad of ways those functions can be automated results in a combinatorial explosion along the two dimensions defined (the human-automation dimension combined with the functional dimension). "How is that aircraft automated?" does not have a simple answer."[30]

Kaliardos continues:

"Finally, human vs automation "error" is sometimes discussed in a misleading way. It is common to hear generalizations such as "human error is a causal factor in 80% of aviation accidents and incidents". These generalizations are then further manipulated through an illogical claim that these errors can largely be eliminated if humans are replaced with automation. That claim is illogical for numerous reasons, such as:

- Automation brings with it other forms of system errors, failures, and behaviors, which typically are not mentioned.
- Human errors are not eliminated when human tasks are replaced by automation, but, rather, shift, often in ways in which errors are more consequential. Overall, changes in automation alter the overall human automation interactions in unpredictable ways.
- Human contributions to safety (vs. human error) outside of safety events leverage resilient behaviors like adaptation but are not well characterized in part because of their subtle roles normal and near-normal operations.
- 'Errors' can be defined in many ways, and a binary definition is a simplification that is not necessarily appropriate for an analysis.
- Many aircraft incidents and accidents involve pilot challenges in understanding the situation, such as diagnosing automated system failure. More sophisticated automation may add complexity and exacerbate this challenge.

"The claim of 'eliminating' human errors through automation substitution is fraught with over-simplifications and misguided assumptions. For reasonably complex systems and operations it is challenging to perform a balanced 'apples to apples' comparison of errors, and human-automation performance in general, without a detailed analysis that considers not only errors, but all relevant behaviors of humans and automated systems that affect safety." [31]

Autonomous Decision-Making: Artificial General Intelligence

The ability to fully replicate human thinking, response, and adaptability on the flight deck will require advances in artificial intelligence, and specifically artificial general intelligence (AGI). Also referred to "human level" or "strong" AI, AGI is envisioned to operate at a level that enables human reasoning, problem-solving, and abstract thinking. However, AGI is still purely theoretical, with no current practical examples. Experts predict that AGI will require several more decades of work to reach an operational state. [32]

30 Kaliardos, William. (2022). Enough Fluff: Returning to Meaningful Perspectives on Automation.
31 Kaliardos, William. (2022). "Enough Fluff: Returning to Meaningful Perspectives on Automation."
32 Mughal, F., Wahid, A., Khattak, M.K. (2022). "Artificial Intelligence: Evolution, Benefits, and Challenges." In: Garg, S., Aujla, G.S., Kaur, K., Hassan Ahmed Shah, S. (eds) Intelligent Cyber-Physical Systems for Autonomous Transportation. Internet of Things. Springer, Cham. https://doi-org.colorado.idm.oclc.org/10.1007/978-3-030-92054-8_4

Integrated Vehicle Health Management

Integrated vehicle health management (IVHM) technology provides real-time, continuous data on the aircraft's state, condition, and dynamics that can be used to inform operators and autonomous systems alike. IVHM is being widely evaluated by both the civil engineering and aerospace industries as a means of monitoring aircraft structures and reducing operational costs. Non-invasive inspection methods and embedded sensors are a key component of IVHM and provide real-time, remote data regarding the state of the aircraft to better inform operators of the condition, operational environment, and dynamic state of the aircraft.[33] Although IVHM has become a standard tool for aircraft certification and fatigue tests, it has not gained widespread use in operational settings.

Some IVHM prototype systems, such as the tail strike indication (TSI) system, are flying on Boeing, Airbus, and military aircraft today. The TSI system utilizes conductive/resistive wiring along the tailfin of the aircraft that alerts the crew of any damage experienced during flight.[34] Challenges remain in achieving comprehensive integrated vehicle health management including the cost of initial implementation, the need for infrastructure to support the large amount of resulting data, and the lack of validation in real operational environments.[35] Due to the long lifetimes of aircraft in typical commercial fleets, changes in aviation technology may take several decades to become widespread.

Cybersecurity

Advances such as remote pilot assistance and autonomous decision-making require a significant reliance on sophisticated communication networks, which are particularly vulnerable to cyberattacks. This presents a safety concern for SPO, as even simple communication jamming could result in significant disruption for aircraft reliant on these technologies. One example is interference (jamming) of sensors or communications systems that could result in impairing any on-board automation.

Another area of concern is that the very technology some say is necessary to support RCO adds risk. Specifically, an enabling capability of some RCO concepts is to provide a data and voice communications channel for a remote pilot on the ground to monitor the flight, and also to potentially assist the pilot on the flight deck. This connectivity creates a cyber vulnerability where a "man in the middle" attack allows an unauthorized person to gain access to the aircraft control channel. One logical response might be to provide the pilot on the flight deck with the ability to disable remote access. However, just when a single pilot needs assistance the most, they lose access. In addition, a remote access lockout would likely prevent another stated benefit of RCO by proponents, which is the ability to intervene in a disabled pilot scenario.

Future air traffic control system technologies may also be another source of cybersecurity risk. The FAA's transition of the national airspace system to the NextGen Air Transportation System (NextGen) system improved aircraft operations, specifically through the implementation of digital data communication and the Automatic Dependent Surveillance-Broadcast system. While these and other NextGen technologies dramatically increase data sharing between aircraft and the ground, they also introduce additional cybersecurity challenges. With autonomous systems layered on top of these air traffic control communications systems, the potential for cyberattacks increases. Research has shown that self-driving vehicles that rely on AI are particularly vulnerable to cyberattack.[36] The addition of signal noise can easily disrupt sensor data and cause catastrophic failure in AI algorithms. Before AI can be used on the flight deck of a two-pilot airline operation, additional research is needed to ensure robust behavior in autonomous systems that can identify hostile inputs. Given the significant challenges of AI in a two-pilot flight deck, it is unfathomable to consider AI as a replacement for a pilot.[37]

33 Qing X, Li W, Wang Y, Sun H. Piezoelectric Transducer-Based Structural Health Monitoring for Aircraft Applications. *Sensors*. 2019; 19(3):545. https://doi.org/10.3390/s19030545

34 *Structural Health Monitoring: NDT-Integrated Aerostructures*. www.compositesworld.com/articles/structural-health-monitoring-ndt-integrated-aerostructures-enter-service (accessed 21 Nov. 2022).

35 Cawley P. Structural health monitoring: Closing the gap between research and industrial deployment. *Structural Health Monitoring*. 2018;17(5):1225-1244. doi:10.1177/1475921717750047

36 Holstein, Tobias, Gordana Dodig-Crnkovic, and Patrizio Pelliccione. "Ethical and social aspects of self-driving cars." arXiv preprint arXiv:1802.04103 (2018).

37 Maple, Carsten, et al. "A Connected and Autonomous Vehicle Reference Architecture for Attack Surface Analysis." Applied Sciences, vol. 9, no. 23, Jan. 2019, p. 5101. www.mdpi.com, https://doi.org/10.3390/app9235101.

Although current academic literature has examined ATC vulnerabilities and system-wide impact modeling, ongoing research into cyber threat response is needed.[38] The jamming and spoofing of satellite navigation systems used by aircraft is on the rise. The use of artificial intelligence, machine learning, self-adapting architecture, and big-data analytics are all valuable tools for identifying and mitigating cyber threats, but need to be employed in conjunction with increased cybersecurity, firewall design research, and data sharing safety.[39] Cybersecurity must continue to evolve as the national airspace system enters an increasingly digital operational environment in order to respond effectively to increasingly sophisticated cyber threats.

Automatic Systems Do Not Replace Pilots

Automatic systems are tools used by two-pilot crews, and these support systems contribute to an excellent commercial airline safety record. The use of increasingly sophisticated automatic systems has improved safety by offloading some tasks, thereby reducing the workload on pilots and allowing them to manage the aircraft more effectively. However, this cannot be a replacement for an actual pilot, especially in the case of non-normal events or an emergency. Automatic systems do fail, and it is not always apparent why given multiple levels of automation and flight modes. Part of the necessary response to automatic system failures is to assume manual control of the aircraft.[40] Because SPO depends heavily on automatic systems, it is important to highlight that these systems are not fail-proof, even for simpler automation tasks, and the flight training to mitigate that has become more complex.

Manual Flight Training Required Due to the Automation of Aircraft Systems

Recent events and studies show that over-reliance on flight deck automation may contribute to short-term episodes of complacency and, if not corrected, de-skilling or skill fade, creating a risk that pilots lose the skills necessary to react appropriately to failures in automatic systems. To overcome skill fade and mitigate the potential for pilots to misdiagnose off-nominal conditions presented by automation, better, timely training is required. According to Capt. Sullenberger, "it requires much more training and experience, not less, to fly highly automated planes."

In late 2022, the FAA re-issued Advisory Circular (AC) 120-123 which discusses flight path management. One notable update to the AC is a discussion on Manual Flight Operations (MFO). The AC discusses the need for more MFO:

> "Operational data have shown that, on average, pilots exercise manual flight control for only a small portion of total flight time (usually only during takeoff and landing). This somewhat limited operational practice in MFO may contribute to a gap between proficiency in MFO and the ability of pilots to perform manual operations when various situations require immediate manual control. Operators should promote and provide pilots with opportunities to exercise their knowledge and skills required for proficiency in MFO in training and during line operations."

The updated AC requires the airlines to add specific training for manual flying operations. Pilots need to maintain this proficiency to ensure that when automation fails, pilots can fully operate the aircraft without reliance on the available automation.

The manufacturers and airlines who are intent upon advancing RCO must also contend with this reality, that pilots need to maintain manual flying skills so that they can fly the airplane during automation system failure. Therefore, the approval for any type of RCO operation will include the requirement for a single pilot to manually fly the aircraft and conduct all duties needed, when automation is unavailable. This is impossible to accomplish reliably and consistently in today's transport category aircraft in normal or routine operations, let alone non-normal or emergency operations.

38 Tamimi, Ali, et al. "Cyber Threat Impact Analysis to Air Traffic Flows Through Dynamic Queue Networks." *ACM Transactions on Cyber-Physical Systems*, vol. 4, no. 3, May 2020, pp. 1–22. *DOI.org (Crossref)*, https://doi.org/10.1145/3377425.

39 Regt, J. de, Moch-Mooney, D., Kirkman, D., Gould, K., & Mooberry, J. (2022). Developing a Roadmap for Autonomy and Air Traffic Management Safety. *2022 IEEE/AIAA 41st Digital Avionics Systems Conference (DASC)*, 1–7. https://doi.org/10.1109/DASC55683.2022.9925763

40 www.skybrary.aero/articles/pilot-handling-skills (accessed November 15, 2022).

New Automatic Systems May Introduce Hidden Dangers

New automatic systems may introduce threats to safety due to lack of redundancy and software glitches that impede a pilot's ability to manually control the aircraft. This highlights the vulnerabilities inherent in automatic systems and the need to have two pilots on the flight deck to help mitigate problems as they arise.

Two high-profile accidents sharing a common cause highlight how new automatic systems can result in catastrophic consequences. Both accidents involved the Boeing 737 MAX, an upgraded variant of the 737-NG featuring upgraded, larger engines. These new engines required installation further forward on the wing than previous variants to allow for adequate ground clearance. To compensate for the resultant shift in the center of gravity, Boeing installed the Maneuvering Characteristics Augmentation System (MCAS), an automatic system that, when engaged, mimicked the behavior of the 737-NG. Essentially, MCAS is a software fix to a hardware problem.[41] The 737 MAX received an amended type certificate by the FAA, but Boeing did not include MCAS in the pilot manual when the aircraft entered service in 2017. Following the loss of two 737 MAX aircraft with a total of 346 fatalities in which MCAS automatically engaged improperly, this omission was revealed as a contributing factor and corrected, and an MCAS fix was developed.

The FAA began requiring all 737 MAX pilots to undergo MCAS-related training in flight simulators by 2021.[42] This case demonstrates that off-nominal conditions presented by automatic systems can be incorrectly interpreted by pilots as they try to regain manual control of the aircraft. Introducing automatic systems is not a guarantee that they will contribute to flight safety in lieu of pilots in control.

41 Hamblin, Matt, "Killer Software: 4 Lessons from the Deadly 737 MAX Crashes," *FierceElectronics.com*, www.fierceelectronics.com/electronics/killer-software-4-lessons-from-deadly-737-max-crashes (accessed November 22, 2022).

42 www.faa.gov/aircraft/air_cert/airworthiness_certification (accessed November 17, 2022).

Section 3: Regulation, Policy, and Public Opinion

The current regulatory environment put forth by the FAA has created an exceptional standard of safety for commercial airline aviation, and at the heart of this regulatory environment is the requirement for two pilots on the flight deck. This environment is not equipped or prepared to enable single-pilot operations, nor should the changes to the current system be undertaken lightly. The FAA's main focus is and should continue to be ensuring the highest possible level of safety for commercial air traffic, rather than enabling risky behavior in the pursuit of lower costs. In addition, any changes to this regulatory and policy status quo should take into account public opinion, which remains skeptical of increased automation.

Regulatory Standards Ensure Safe Operations

The FAA's mission is to "oversee and operate the safest aerospace system in the world, all with a culture of continuous improvement."[43] Indeed, the FAA is on track to meet its goal of "[reducing] commercial air carrier fatalities per 100 million persons on board U.S. carriers by 50 percent over [an] 18-year period [from] FY 2008–2025."[44] Single-pilot operations would put this goal at serious risk.

The requirement for two pilots is at the heart of this exemplary standard of safety. There are numerous FAA safety regulations explicitly requiring multipilot operation. As one example, FAR 121.385 mandates that "the minimum pilot crew is two pilots and the certificate holder shall designate one pilot as pilot in command and the other second in command." The regulation also provides that "in any case in which this part requires the performance of two or more functions for which an airman certificate is necessary, that requirement is not satisfied by the performance of multiple functions at the same time by one airman." These safety regulations have been successful and have contributed to U.S. aviation's exemplary safety record. These regulations ensure two pilots are available to manage high workloads from the many simultaneous tasks required to ensure safe operation of the aircraft. These periods are not just during taxi, takeoff, and landing, but also during high-altitude cruise when there is adverse weather, turbulence, or emergency situations. To ensure safe operation of aircraft, the regulations require two-pilot operation even during periods of low workload..

Other FAA safety regulations have the concept of multipilot operation embedded within them. Indeed, multipilot operation is fundamental to many aspects of FAA safety regulation—from aircraft certification to operation. Single-pilot operation would undercut these other aspects of FAA safety policy and regulation. For example, single-pilot operation would undermine the concept of and requirements for crew resource management, which is a critical concept in ensuring the safety of the skies. Crew resource management is a philosophy that encourages workload and decision making to be shared endeavors; because of its record of success, is has become deeply embedded both in the culture of aviation and in safety regulation.

Some FAA safety guidance, such as FAA Advisory Circular 25.1523, delineate the serious risk of single-pilot operations. That document noted the differences in pilot incapacitation–caused accidents in general aviation

43 FAA Strategic Plan, FY 2022-2026. www.faa.gov/general/flight-plan-21
44 FAA Performance and Accountability Report, FY 2022. https://www.faa.gov/sites/faa.gov/files/afn-20221115-faa-par.pdf

(Part 91) and small plane commercial charter aviation (Part 135). For example, the circular noted 32 occurrences of pilot incapacitation in Part 135 operations resulting in 32 fatalities. The National Transportation Safety Board (NTSB) attributed all of these to single-pilot operations. The FAA noted that, "relative to Part 121 operations over the same time period, there were 51 pilot incapacitation occurrences which resulted in a normal recovery of the aircraft by the other pilot."

Many of the arguments in favor of single-pilot operations are rooted in economics rather than safety. Aviation is the safest mode of transportation in part because economic arguments often take a back seat to safety requirements. To maintain its global standing as a leader in aviation safety, the FAA needs to avoid even the appearance of regulatory capture; adopting regulations for economic reasons rather than safety reasons. Lapses that occurred during the 737 MAX certification led to concern about the FAA's international standing.[45] Indeed, the impressions created by the MAX certification have led to reform legislation enacted by Congress and caused the FAA to redouble its efforts to ensure the safety of the skies. For example, in the FAA's 2022 business plan, the agency is planning to improve its aircraft certification process to enhance current and future safety efforts.[46] Notably, ALPA applauds that the FAA business plan does not reference efforts to allow single-pilot operation of aircraft.

Regulator Activities Regarding RCO/eMCO/SPO

Federal Aviation Administration

The FAA has continued to put safety before economics when it comes to the introduction of concepts or capabilities where reduced-crew operations have been proposed. The FAA has also wisely taken a cautious approach to sub elements of RCO/eMCO/SPO, including artificial intelligence and advanced levels of aircraft system automation.

It is important to note that the FAA has taken a data-driven approach that is consistent with their safety-before-economics philosophy. The FAA has conducted joint studies with NASA on the hazards and risks associated with single-pilot or reduced-crew operations that are similar in concept to eMCO operations. These studies are foundational to establishing any official position or definition of a suitable pathway for eMCO or other types of operations.

A FAA and NASA joint study in 2017 concluded that:

> "When the pilot workload exceeded certain limits, the pilots would shed tasks and in doing so, errors in execution or omission would occur."[47]

45 Lardner, Richard; Krisher, Tom, "Criticism of FAA mounts as other nations ground Boeing jets," AP News, March 13, 2019, (https://apnews.com/article/ethiopia-indonesia-us-news-ap-top-news-international-news-0d26ade6ff9044d2b8c81fc8000d61cb)

46 FY 2022 FAA Business Plan, Federal Aviation Administration, 2022, www.faa.gov/sites/faa.gov/files/2022-02/FAA_FY22_Business_Planv2.pdf

47 An Assessment of Reduced Crew and Single Pilot Operations in Commercial Transport Aircraft Operations, p. 6

Furthermore, in the white paper published by ALPA in 2019, flight-path performance was better during two-crew operations than reduced- or single-crew operations:

> "Two pilots provided for a pilot monitoring. Two-crew operations provided four hands, four eyes, and two brains to monitor and work the problem[s]. Two pilots provided for workload sharing, especially in the rudder trim runaway non-normal where the physical workload to control the vehicle was significant. Two pilots provided a larger wealth of experience from which to draw from such as adapting to unique flying techniques [using asymmetric thrust to help balance fuel load or rudder trim], knowing nearby available, suitable, but underused airports [Grand Junction, CO], or understanding secondary or compounding failure effects that are not checklist items [loss of generators will cause pressurization effects]."[48]

An FAA study of data itself has said that,

> "only one out of every 10 flights conforms to the plan originally entered into an aircraft's flight management system."[49]

It is imperative that the FAA recognizes the work that they have done in the past, to uphold the highest safety standards that are in place for a reason and a part of that is the fact that there are two pilots on the flight deck. As in 2018 with the FAA Reauthorization Act, ALPA stood its ground on the language that was contained in Section 744:

> "While we applaud Members of Congress on their efforts regarding the release of the FAA Reauthorization Act of 2018, we are deeply concerned with the language contained in Section 744—a provision that would introduce significant aviation safety and security risks for cargo aircraft. Specifically, this provision establishes a research and development program in support of single-piloted cargo aircraft assisted with remote piloting and computer piloting.
>
> "The professional cargo pilots of our collective airlines strongly oppose Section 744 and implore Congress to reject this provision without delay. By endorsing language that promotes single-operator commercial cargo aircraft, Congress will undermine years of safety and security measures currently in place and put lives at risk.
>
> "The desire by some in the industry to pursue single-piloted or autonomously piloted cargo aircraft seriously places the American public and the flight crews of these aircraft in a tenuous position. For many years, aviation has been the safest form of transportation in the United States. This is by no means an accident; it is the result of a strong regulatory framework built over time, paired with an ongoing airline system safety culture that is one of the most ambitious in our nation's history. Attempts to roll back safety regulations in such a way are counterproductive, and unacceptable to the common good. With the increasing frequency and severity of reports regarding computer hacking, accidents in current military and civilian drone operations, and mounting reports of autonomous vehicle accidents, we think any serious consideration of this technology is premature at best."[50]

ALPA will always hold regulators accountable to the necessary degree in terms of aviation safety, and will not sway on ensuring that the best way to do that is a well-rested, trained, and experienced two-pilot flight deck.

48 Ibid., p. 6

49 Report on the Operational Use of Flight Path Management Systems, p. 29

50 ALPA Press Release: Cargo Airlines Respond to FAA Reauthorization Section 744 Language—FDX MEC Communications, https://fdxcomm.alpa.org/press-release-cargo-airlines-respond-to-faa-reauthorization-section-744-language

European Union Aviation Safety Agency

The European Union Aviation Safety Agency (EASA), however, has put economics before safety. They have been transparent about their belief that reducing crews on the flight deck of transport category aircraft is an important step that needs to be taken. Given the announcement of projects underway at Airbus and Dassault, it came as no surprise that EASA has initiated a safety study on eMCO and SPO, *after* their decision to find a certification pathway to achieve the eMCO/SPO concept. Unlike the FAA, where safety comes before economics, it seems that EASA decided to undertake the safety case after they decided to support manufacturers who were working toward an eMCO/SPO aircraft certification pathway.

It has become very apparent that EASA has been working with EU aircraft manufacturers (Airbus and Dassault) to develop criteria for the development of eMCO and SPO on specific aircraft with the ultimate goal of eliminating a two-pilot flight deck. According to a safety risk assessment framework drafted and published by EASA, the objective of EASA as well as the EU aircraft manufacturers is to assess the issues and the feasibility of the implementation of eMCO in the EU regulatory framework by 2025, and then assess the issues and the feasibility of the implementation of SPOs in the EU regulatory framework by 2030. This is an aggressive timeline with no data or information to justify such a drastic degradation of safety in the aviation industry.[51]

The study evaluates at a top level:

- Pilot workload
- Pilot error
- Pilot incapacitation
- Fatigue
- Sleep inertia
- Breaks due to physiological needs

In the EASA work that has been completed so far, there are two areas where it seems the introduction of eMCO to commercial flight would cause vastly more stress and increase workload management with decision making than in a regular two pilot flight deck system that is standard in aviation today.

EASA Work on Pilot Flying Incapacitation

In a recently published document by EASA, there is discussion of incapacitation of the single pilot flying the airplane:

> "Incapacitation of the pilot flying during the eMCO segment results in a situation where the aircraft is momentarily not controlled by a human pilot. It is possible that the pilot flying is able to self-detect a [gradual] incapacitation and alert the PR. In any case, an on-board pilot monitoring system is expected to detect incapacitation of the pilot flying, alert the pilot resting and maintain the aircraft in a stable state until the pilot resting is able to take control of the aircraft. The incapacitated pilot must be placed in a neutral position to avoid inadvertent interference with flight controls and aircraft systems. The pilot resuming flight will need to divert the flight according to the procedures briefed at the start of the eMCO segment and inform ATC of the emergency situation."[52]

In this case, not only is it assumed that the aircraft and its systems can handle the flying during the pilot incapacitation, but also that the onboard pilot resting will be awoken immediately by the monitoring system. It is also assumed that the pilot will have the wherewithal to proceed to the flight deck, make sure the incapacitated pilot has not set the controls for the aircraft during incapacitation into an unusual attitude, and then it is assumed

51 eMCO-SiPO—Extended Minimum Crew Operations—Single Pilot Operations—Safety Risk Assessment Framework, www.easa.europa.eu/en/research-projects/emco-sipo-extended-minimum-crew-operations-single-pilot-operations-safety-risk

52 NLR/A.L.C. Roelen, EASA 2023. eMCO-SiPO—Extended Minimum Crew Operations Single Pilot Operations: D-1.2 Baseline Risk Assessment Framework.

that the pilot can proceed to steady the incapacitated pilot to a position that does not interrupt recovery, and then finally, take all the workload on.

Clearly there are a lot of questions and concerns with how this scenario would play out in a real-world situation. A well-rested two-crew flight deck typically sees what is happening when pilot incapacitation does occur and can immediately counteract the situation. Stepping into the situation after resting can prolong the process and timeframe in which drastic intervention and decision making is needed immediately.

EASA recently published documents that address system malfunction situations

> "The scenario for an aircraft system malfunction is generic for all systems [hydraulic, electric, etc.] with the exception of a fuel leak, aircraft depressurisation, unreliable air data and engine failure which are described as separate scenarios. A system malfunction will be detected by the pilot flying when prompted by the aircraft's alerting system or due to secondary cues such as loss of system performance or unexpected system parameter values. The pilot flying will reconfigure the system as per the appropriate procedure [and prompted by the aircraft's system display]. Complex failures requiring substantial decision making or failures that result in significant loss of system performance may require abort of the eMCO segment."[53]

Many situations that occur on the flight deck are addressed by a two-flight crew and go unnoticed by many. The two pilots working as a team are trained for the situation and know how to respond in a timely manner to get the job done, as well as being able to communicate with one another. For decades, the crew resource management flight deck philosophy has prevailed and is hailed as a significant safety tool. It makes it very clear what the roles of the pilots are to distribute workload, and to determine who is to run a checklist and make calls while the other pilot troubleshoots the issue. Relying on an automation system notifying the single pilot on the flight deck that a failure of a system has occurred is a counterintuitive solution to maintain safety. Two pilots working together can troubleshoot many issues that arise. A proposal to rely on a new automation system to make critical, timely, and accurate life-saving decisions while the second pilot is resting is a backwards approach to safety.

The European Cockpit Association (ECA) has observed that when it comes to the thought of automation or eMCO operations, "The equation "two-pilots on the flight deck + AI" enhances safety. Conversely, the equation "one pilot on the flight deck + AI" poses important threats to safety. In the last 10 to 15 years, we have seen many cases where technology has compromised safety and only the coordinated work of a crew (two pilots or more) saved the day. Aircraft manufacturers and certain regulators make unsubstantiated claims that the technology is ready for eMCO and will lead to enhanced safety. But this raises the question as to why this technology is not made available to be implemented within the two-pilot flight deck and thereby to enhance safety even more."[54]

After intense scrutiny by the global aviation unions including ALPA, IFALPA, and ECA, EASA has now said no operational approvals for airlines to conduct eMCO are expected before 2027, and SPO operations will be much further down the road. However, EASA has not announced any slowdown in their work plan, or even a termination of the work that was ongoing. Interestingly enough, while regulators will ultimately be the deciding factor when it comes to the potential introduction of concepts like eMCO and SPO operations, original equipment manufacturers (OEMs) have taken matters into their own hands on the concept.

53 NLR/A.L.C. Roelen, EASA 2023. eMCO-SiPO—Extended Minimum Crew Operations Single Pilot Operations: D-1.2 Baseline Risk Assessment Framework.

54 eMCO_SiPO_PP_21_0719_F_0.pdf (eurocockpit.be)

ICAO Assembly

At the 41st ICAO Assembly in September 2022, the topics of eMCO and SPO were brought before the assembly for consideration and presented by Costa Rica and IFALPA in regard to the development of eMCO testing with OEMs and EASA:

> "…extended minimum crew operations [eMCO] and single pilot operations [SiPO], are currently being considered for implementation in the near and mid-term future. Both concepts would reduce the current number of required pilots present in the flight deck during operations to a single pilot and raise great concern due to significant new risks with unknown consequences. It is imperative that any future evolution of this benchmark improves upon and does not degrade the safety and security level in any area. Where eMCO are concerned, the concept lacks both maturity and statistical proof of increased safety with the proposed enabling technology."[55]

The role of the ICAO Assembly is to address the shortfalls and safety risks. A proposal submitted by EASA to initiate work on the subject of eMCO and SPO operations resulted in the ICAO Assembly determining whether or not to devote any resources and work commitments to develop a new work project. IFALPA and Costa Rica raised concerns and indicated that safety and security would be jeopardized with eMCO technology because it is far too novel and has far more unknown consequences than benefits at this time.

Ultimately the Assembly decided that current eMCO proposals lack safety risk assessment and data, let alone independent research which is necessary for ICAO to devote resources to on the subject. Costa Rica and IFALPA stated in their discussion that:

> "There are many reported examples of incidents where two, or more, pilots on the flight deck were needed to recover from equipment malfunctions and other events that otherwise may likely have led to a negative outcome. Two pilots seated side by side in the flight deck can closely coordinate their actions via constant communications, including nonverbal cues. The pilot monitoring also plays a vital role in observing the performance of the pilot flying, watching out for errors or declines in cognitive ability. Should the pilot flying become incapacitated for health reasons during a flight, the pilot monitoring can quickly take control of the aircraft. Importantly, extensive study would be necessary to properly understand the physiological and psychological effects on the remaining pilot who would be working alone on the flight deck for extended periods of time."

Costa Rica and IFALPA also stated that:

> "Concepts such as eMCO are fundamentally rooted in economic arguments based on increasing pilot flight duty productivity. History has shown that putting economic gains, even if innovative, as the primary goal tends to have a detrimental effect on safety. The safety and security risks, as well as the challenges associated with reducing flight deck crews, may well outweigh any potential benefits."[56]

As a result of the debate at the ICAO General Assembly, the topic of opening a work program for eMCO was not approved, however it was not outright rejected either. This means that ICAO may decide to begin work on the topic as their resources allow. Clearly, the aviation industry is constantly changing with new concepts and entrants trying to gain access to airspace. It was good to see these concepts were pushed aside, however it will certainly not be the last time that these concepts are brought to the Assembly's attention.

At the 67th ALPA Air Safety Forum in September 2023, when an IFALPA representative on the RCO panel was asked to share an update on any work at ICAO on the eMCO working paper, their response was, "it is still there but has moved to the bottom of the priority list, but I am sure that we will see it again."

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55 Extended minimum crew operations, www.icao.int/Meetings/a41/Documents/WP/wp_323_en.pdf
56 Ibid.

OEMs

There is no coincidence that Airbus and EASA had a coordinated approach to the introduction of eMCO operations. Over the past year, news articles have brought many of the Airbus and EASA eMCO plans to light. ALPA has compiled the information here as a summary of publicly shared information.

In early 2022, a project coined "Project Morgan" by Airbus was presented to FedEx management with a concept to introduce two new freighters to the company and the potential of eliminating a pilot onboard as time progressed. An *Aviation Week Article* published on October 4, 2023, revealed two extremely radical concepts. One proposal is an A321F "that would be type-rated for two pilots at the outset but would attain single-pilot approval over time. The second concept is an A350F approved for eMCO—essentially permitting one pilot on the flight deck during low-workload cruise portions of the flight, which could lead to needing fewer pilots on long-haul flights that require relief crews under current regulations."[57]


Planes can be flown with 'just one pilot', says Airbus chief

A subset under Project Morgan, dubbed "Dragonfly," would further develop eMCO concepts such as automated emergency descents. The timeline of Airbus' pitch aligns with what EASA had hoped to be accepted work done on its eMCO and SPO study, with implementation of the A350F slated for service in 2026 with some accepted RCO standards followed by rulemaking made on standards by EASA and the FAA. Fortunately, both regulator and manufacturer have backed off on their timetable for initial implementation.[58]

However, Acting Executive Director Luc Tytgat of EASA was quoted in the article as saying "We have been asked to look at single-pilot operations [for freighters] as industry has been approaching us to look at the viability of the case. We don't have yet a pre-application, just . . . a partnership agreement with the industry actor. They want to question us [on] whether it is realistic or not. We are at step zero of the process."[59] Meaning that although the timeline has changed, a present and consistent threat of the industry lowering safety standards for financial benefit remains.

The A321F SPO plan included application to both EASA and FAA in 2023 and entry into service in 2027, according to the documents. In parallel, Airbus would support development of what it dubs the "single pilot/ second pilot-optional" certification project that would pave the way for full-mission SPO. FedEx management would work with the FAA on operational details, including a pool of pilots trained to fly either alone or in traditional crew pairs. The ambitious project aimed for entry into service by 2030.[60]

ALPA, IFALPA, and ECA, as well as the global pilot community, including the Associations of Star Alliance Pilots, the Oneworld Cockpit Crew Coalition, and the SkyTeam Pilots Association, are united in the fight against reduced-crew operations and will do everything in their power to ensure the current standards that have made aviation the safest form of transportation in the world will not be eroded.

"We've been told that North American passenger operators are not interested, and the legacy European operators are not interested," said ALPA president Capt. Jason Ambrosi in a September 2023 *POLITICO* article. "But they all understand that if some are allowed to do this it puts significant operational pressure" on them.[61]

In 2023, a global coalition was formed in order to prevent airlines and manufacturers from pushing ahead with plans to remove pilots from the flight deck. Pilot representatives from IFALPA, ECA, and ALPA vowed to

57 Broderick, Flottau, Dubois, "Single-Pilot Operations Are Under Increased Scrutiny," Aviation Week Network, https://aviationweek.com/air-transport/safety-ops-regulation/single-pilot-operations-are-under-increased-scrutiny

58 Ibid.

59 Ibid.

60 Ibid.

61 Eccles, Daughtery, "Planemakers Look to a Pilotless Future," *POLITICO* www.politico.eu/article/planemakers-mull-pilotless-future-aircraft-easa-klm-aviation

take collective action to protect the flying public and counter an aggressive corporate-led lobbying campaign targeting regulators around the world, including the International Civil Aviation Organization (ICAO). The global pilot community, including the Associations of Star Alliance Pilots, the Oneworld Cockpit Crew Coalition, and the SkyTeam Pilots Association, are united in the fight against reduced-crew operations and will do everything in their power to ensure the current standards that have made aviation the safest form of transportation in the world will not be eroded. For more information on these collective efforts, visit www.safetystartswith2.com.

Capt. Ben Mansumitchai, IFALPA; Capt. Jason Ambrosi, ALPA; and Capt. Otjan de Bruijn, ECA

Public Opinion

Public opinion also presents a barrier for any changes to the currently regulatory and policy environment. The public continues to believe air transportation is the "least suited" mode of transportation for the implementation of self-driving technologies,[62] according to a 2022 poll conducted by Ipsos surveying over 1,000 Americans. Since 2018, more Americans are receptive toward self-driving technology (35% vs. 19% in 2018). Nonetheless, the general public is hesitant toward automation in commercial aviation. About 53% of survey participants indicated that they would not be comfortable with a single pilot taking them to their destination, while 80% of participants are not comfortable with remote piloting.

80%

Not Comfortable with Remote Piloting

A Stewart & Harris (2019)[63] study assessing passenger attitudes toward single-pilot commercial operations shows that passengers have concerns about SPO. Participants' concerns were about the remaining pilot's mental health, distrust of autonomous software, and possibilities of pilot incapacitation. Participants expressed a need for further awareness of and for airlines to effectively enforce and communicate safety standards for SPO.

In regard to policy priorities for improvements to air travel, the public strongly preferred other uses for public resources spent on aviation developments, such as reducing emissions (56%) and modernizing air traffic control to reduce delay (51%). Only 11% of participants were interested in prioritizing single pilot operations for cost-savings.

62 Ipsos Public Poll Findings, 2022

63 Stewart, N. & Harris, D.,"Passenger Attitudes to Flying on a Single-Pilot Commercial Aircraft," Coventry University. 2019. pp.77-85. https://pure.coventry.ac.uk/ws/portalfiles/portal/26026940/Binder2.pdf

Section 4: Advanced Air Mobility (AAM)

ALPA has always been a proponent for advancing aviation safety for not only the national airspace system, but also the public that utilizes aviation. However, with the increase in technology and the push for rapid advancement of new entrants, ALPA is steadfast in the belief that safety will always be the number one priority, and the constant push from private sectors is worrisome when no safety data has been collected. The following sections discuss AAM advancement and the potential hazards that may be applied to commercial operations.

Overview of AAM Activities

The introduction of urban air mobility (UAM) vehicles in urban settings can change public perception towards SPO and aviation. Investors of UAM companies are major airlines and aircraft manufacturers, therefore, success in UAM/AAM may lead some to consider migration of automation technology and practices related to SPO to traditional commercial aviation. Furthermore, legislative interests to license UAM vehicles could have an impact on regulations in Part 121. However, AAM is a very different environment to Part 121 and there are appropriately different regulatory standards for operations under Part 121. Substantial differences between AAM and commercial aviation include varied operating environments and economic cases, and it would be premature to apply advances made in AAM to current passenger and cargo aviation operations.

AAM refers to "new aviation operations that transport passengers and cargo short/medium distances using new and emerging aircraft technologies."[64] NASA has identified three categories of primary missions: UAM, small uncrewed aircraft systems (sUAS), and regional air mobility (RAM). This white paper focuses on the growth of sUAS and UAM markets and the potential impacts of these markets to commercial aviation.

Small uncrewed aircraft systems refer to small, uncrewed aircraft with vertical takeoff and landing capability (VTOL) and are often used for local package delivery, inspection, disaster response, and mapping. Some sUAS are also capable of flying beyond visual line of sight (BVLOS) or equipped with geofencing capabilities. UAM refers to aviation transportation systems using highly automated aircraft that transports passengers/cargo at lower altitudes, within urban and suburban areas. [65] UAMs include electric VTOL (eVTOL) aircraft and helicopters, mostly used as air taxis, ambulances, and personal vehicles. Many operators are performing regular eVTOL testing and have received significant investment payments from traditional aviation manufacturers, such as Embraer, Boeing, and Airbus. Airlines, such as Delta, American Airlines, and United have placed orders for UAM vehicles.[66] Technological developments for UAMs have also led to progress in network integration and airspace management.

Additionally, drone operators have begun commercial operations across selected U.S. states and around the globe. UAS operators have received significant investment from traditional delivery operators such as FedEx,

64 AAM Vertiport Automation Trade Study. NASA. https://ntrs.nasa.gov/api/citations/20210009757/downloads/20210009757_MAJohnson_VertiportTradeStudy_final.pdf

65 Ibid.

66 "United pre-pays eVTOL firm Archer $10 million of $1 billion UAM order." DroneDJ. https://dronedj.com/2022/08/11/united-archer-evtol-uam

Amazon, and DHL, and saw technological progress made in BVLOS, autonomous flights, detect and avoid, and navigation for UAS. There is increased support from the FAA to explore a new regulatory framework for BVLOS and congressional pressure to increase the pace of licensing. In 2022, Congress created the Congressional AAM Caucus, and the Senate and House of Representatives passed the Advanced Air Mobility Coordination & Leadership Act (S.516).

Potential Impact to Single-Pilot Operations

AAM advances are currently in FAR Parts 135, 91, and 107, regulating environments where the FAA has established different safety standards that enable new technology to be introduced to operations more rapidly. Market activity from AAM expansion may increase awareness of SPO and improve public comfort. The introduction of RAM services may overlap with and affect commercial aviation operations. AAM investment from airlines and aircraft manufacturer may lead to greater integration of SPO-related technologies into Part 121 operations and future aircraft designs. UAM advances in network integration and airspace management may enable greater autonomy in commercial operations while sUAS advances in BVLOS and detect-and-avoid technology could drive future technology development in commercial remotely piloted operations. Legislative changes could also affect Part 121 as proposed Part 108 BVLOS regulations may set precedents for regulations in crewed aircraft and creation of new frameworks. Additionally, FAA's collaboration with international partners on AAM certification may also lead to rapid adoption in the United States.

Many UAM companies are interested in transitioning to fully autonomous operations to reduce operating costs. AAM firm Wisk Aero advocates for automating procedures such as consulting manuals and checklists, suggesting that autonomous vehicles are more responsive than a remote pilot or a less experienced pilot .[67] Morgan Stanley estimates autonomous flying taxis may be worth $1.5 trillion by 2040.[68] Companies argue training eVTOL pilots is a high-cost factor, and removing the pilot can lead to higher revenue per ride and cut costs as high as 23% of total eVTOL costs.[69-70] It is likely companies may explore SPO concepts for commercial aviation upon UAM success.

Different Environments, Different Rules

Despite the potential for impact, there are important differences in the regulatory and operating environments between commercial aviation and advanced air mobility. AAM technologies like UAM/sUAS operate in Part 91/135/107 while commercial aviation operates in Part 121. Part 121 has the highest operating air safety standard, with a lower risk tolerance. Part 135 can operate with less than 30 passengers while Part 121 refers to scheduled air carriers, which can transport up to 545 passengers on an Airbus A380. Therefore, the risk tolerance is not transferable from Part 135 to Part 121. Part 121 further requires two pilots on the flight deck; therefore, it is unlikely that the one pilot minimum requirement from Part 135 can migrate to Part 121. Furthermore, AAM platforms have a different airworthiness standard (Part 23) than commercial aviation (Part 25), which has a higher safety standard and more restrictive conditions, Therefore, it is unlikely technology introductions in AAM can affect Part 25 standards.

Additionally, it is uncertain that AAM operations will be widely adopted. AAM's uncertain economic case indicate AAM is unlikely to affect commercial aviation in the short term and autonomous UAM may not be profitable,

67 "Boeing's Wisk Is Going Full Robot With Its Electric Air Taxi While Competitors Stick With Human Pilots," Forbes, 2022. www.forbes.com/sites/jeremybogaisky/2022/10/04/boeing-wisk-autonomous-evtol/?sh=411a5f6a6603

68 "Flying taxis could lift off in six years," CNBC, 2019. www.cnbc.com/2019/06/13/lilium-five-seater-electric-air-taxi-how-much-does-a-ride-cost.html

69 "How Much Will It Cost to Fly on eVTOL air taxis?," Flying Mag, 2021. www.flyingmag.com/evtol-air-taxi-passenger-prices

70 "Study questions air taxi cost structure, passenger prices," DroneDJ, 2022. https://dronedj.com/2022/11/14/study-questions-air-taxi-cost-structures-passenger-prices

even if the pilot is removed. Archer, Eve, Lilium, Joby, and NASA estimate an air taxi ride will cost anywhere from $2 to $11 per passenger/mile.[71] Since air taxi seat per mile is comparable to luxury car rate at $3.75 per passenger/mile, eVTOLs initial service will not be affordable to the general population. The expected low seat occupancy rate of 2.3[72] passengers per aircraft[73] thus raises uncertainty about mass adoption and UAM's business case.

While most UAM operators have identified 2024 as the initial operations date, by 2022, manufacturers such as Joby have pushed the launch date further to 2025.[74] This suggests over optimism in the eVTOL industry when many operators are falling behind their targeted operations schedule, citing manufacturing and regulatory delays.[75] Additionally, technology progress and safety remain a concern, as Joby Aviation's vehicle failed during a test flight.[76] Investment momentum may have slowed as Volocopter and Archer Aviation both have cancelled their planned SPAC mergers. [77]

71 "How Much Will It Cost to Fly on eVTOL air taxis?," Flying Mag, 2021. www.flyingmag.com/evtol-air-taxi-passenger-prices
72 Ibid.
73 Ibid.
74 "Joby pushes launch to 2025," AOPA, 2022. www.aopa.org/news-and-media/all-news/2022/november/09/joby-pushes-launch-to-2025
75 "Joby pushes back eVTOL service launch due to regulatory, internal delays." Flying Mag, 2022. www.flyingmag.com/joby-pushes-back-evtol-service-launch-due-to-regulatory-internal-delays
76 "NTSB: Joby experienced component failure during February crash," Vertical Mag, 2022. https://verticalmag.com/news/ntsb-joby-experienced-component-failure-during-february-crash/
77 "Volocopter cancels SPAC," UAS Vision, 2021. www.uasvision.com/2021/12/08/volocopter-cancels-spac-crowdfund-investors-furious

Conclusion

As mentioned in ALPA's 2019 whitepaper, there are, and will continue to be automation and technological advancements that help to enhance safety and operational efficiency. However, the enhancements are there to support — not replace — pilots in the performance of their duties. The data and facts presented in this updated whitepaper undeniably support what should be obvious to all: reducing or eliminating pilots from the flight deck of an airliner, is a bad and dangerous idea.

The two pilots on the flight deck of every airline flight, with their exceptional and uniquely human ability to adapt to unexpected circumstances, remain irreplaceable despite advances in technology. The complex, real-time decisions that must be made in a highly dynamic and often unpredictable environment requires human oversight and intervention, no matter how sophisticated the technology, especially when that technology malfunctions or fails.

The push to reduce the number of flight deck crew is motivated primarily by economic considerations, an approach that unquestionably compromises the well-established safety practices that have made air travel the safest mode of transportation in the world. Passengers and cargo shippers trust that their flights are being managed by two professional pilots who, working as a team, can respond effectively to abnormal events and emergencies when they arise. Undermining that trust and well-established safety record for the sake of cost-cutting could have detrimental effects on the industry.

ALPA remains steadfast in its commitment to upholding the highest safety standards. We urge industry stakeholders, regulators, and the public at large to reject the concept of Reduced Crew Operations and continue to support the presence of at least two highly trained, experienced, and well-rested pilots on every flight. By doing so, we can ensure that our air transportation system remains an example of safety and reliability for generations to come.

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