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Examining the Future of Automation in Commercialized Flight and its Impact on Airline Pilots

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The purpose of this study was to focus on the perceptions of an automated (unmanned) flight deck and its intended implementation in the U.S. airline industry. The objective was to understand fully autonomous aircraft's influence on commercial pilots, as well as investigate the effects on the U.S. airline industry and human-machine interaction. Commercial airline pilots, including ranks of both Captains and First Officers (FO) in Part 121 scheduled service, were the research population for this study. The sample population number was 15 U.S. airline pilots offering various diversity in age, gender, years of service, airline employer, and military or civilian flight experience. The semi-structured qualitative research consisted of developing a deeper understanding of the pilots' perceptions of the three-pronged approach: (1) the psychological barriers and motives of the pilot, (2) the differences in aircraft ground-based safety and training, and (3) pilots' understanding of the timeliness of entry for unmanned flight deck operations to reach FAA standards. The study consisted of participant interviews utilizing a series of ten structured and semi-structured interview questions. The findings concluded that pilots are aware of the workload changes that are present with implementing fully autonomous aircraft in the Part 121 category. Two themes became evident when discussing workload changes. First, the role of the pilot changes from a single flight focus to a multi-flight monitor. Secondly, as technology advances, the pilot's physical workload of hand flying an aircraft will constantly deteriorate. Furthermore, the advancement of a fully automated flight deck and its effects on the U.S. airline industry can potentially have significant impacts on the psychology of commercial airline pilots. While pilot responses varied based on individual experiences, attitudes, and adaptability, there were several psychological responses identified in this study, including (1) loss of control, (2) uncertainty toward technology, (3) job insecurity, and (4) adaptability. Last, the advancement of a fully autonomous flight deck will obviously create additional concerns for U.S. airline passengers. The most significant concerns for passengers included (1) safety, (2) trust, (3) passenger-pilot relationship, and (4) understanding of technology. Passengers will always question if modern technology has been thoroughly evaluated and if it can react to unexpected situations as safely and effectively as a human.

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Introduction

"I'm in a knife-fight with this plane. It isn't a fair fight; knife-fights never are," (Sullivan, 2019, p.2). Qantas Flight 72 experienced this war to stay alive on October 7, 2008. Over the West Coast of Australia, the flight deck realized their autopilot malfunctioned as passengers and crew members experienced roller coaster-like conditions, seriously injuring flight attendants and leaving many unconscious (Doran, 2020). What caused this erroneous malfunction in automation that lasted ten minutes? The answer to this question relies heavily on the industry's overruling machine trust and pilots' lack of ultimate control authority, resulting in the greatest growing concern in the commercial aviation industry (Borenstein et al., 2020). This dependency on automation raises a series of questions about the correspondence between heavily automated systems and pilots. These automated systems refer to the systems that manipulate the flight controls to simulate pilot input. The human-machine interface within the aviation industry has changed the relationship between humans and aircraft forever.

Automation already plays a massive part in commercial aviation. Even though automation has brought many benefits to aviation, the rise of automated technologies has eliminated many routine pilot functions. Today, most modern aircraft are controlled mainly by computers, with automatic flight management systems (Bertram, 2019). This broadened term *flight deck automation* now encompasses advanced systems such as aviation robotics, artificial intelligence (AI), programmed route monitoring, and calculation of judgment control (Prahl et al., 2022). Recent additions to flight deck automation include automatic route modifications, procedure warning systems, increasing flight management system (FMS) capabilities, automatic braking for smooth deceleration, advanced autothrottle control operations, and in-flight weather forecasting, all of which combine three sensors for judgment control related to AI (Prahl et al., 2022). This is described as the cluster of technologies that are essential to the modern flight deck throughout the monitoring and decision-making process for commercial flight (Prahl et al., 2022). Pilots can, of course, take over the controls – but flight management systems and processes are in place to allow aircraft to operate under considerable automation, and in fact, this has become the accepted norm for commercial aviation.

Within the commercial aviation industry, safety and pilot training remain the main concerns as automation technology continues to progress. Although flight deck automation rarely fails outright due to increasing reliability, issues are nonetheless encountered when the automation fails to adequately consider associated human factors and challenges or when it encounters situations that were not anticipated by its designers (Hart, 2020). As automation comes closer to removing pilots from the loop, it paradoxically generates more human factors and challenges, not only when it fails to function as designed but also when it does function as designed (Hart, 2020).

Statement of Problem

Although many factors prevent the advancement of aircraft automation, such as time necessary for technology innovation, increasing complacency of pilots, lack of funding sources, and slowness of market entry for manufacturers, the real problem is an extension of three barriers that limit its progression (Trop, 2023; McFadden, 2021). The three barriers that limit the advancement of aircraft automation are:

1. The human population is not ready to fly aboard commercial aircraft with no human pilots. The thought of having complete faith and confidence in a fully automated aircraft is daunting and ominous due to previous flight accidents.
2. Aircraft and ground-based safety automation procedures and training do not meet the needs of development, implementation, and maintenance standards for commercial flight.
3. FAA airworthiness certification for fully autonomous commercial aircraft is uncharted territory.

The combination of these three statements depicts the limitations restricting fully automated commercial aircraft, computer systems entirely replacing human pilots, and the barriers to entry. The impact of these barriers may include (1) a continuous decline in passenger confidence in automated systems, (2) a decrease in National Automation Programs, (3) a rising concern about policies, guidelines, and procedures for automation and information systems, (4) a decrease in priority for aircraft certification of automation programs, and (5) an increasing financial risk for airlines to offer fully automated flight.

Purpose of the Study

The purpose of this study was to focus on the perceptions of an automated (unmanned) flight deck and its intended implementation in the U.S. airline industry. The objective was to understand fully autonomous aircraft's influence on commercial pilots, as well as investigate the effects on the U.S. airline industry and human-machine interaction. There have been many research studies that have been written about pilots' acceptance of automation, but few, if any, detail the pilot's perception of the future of fully autonomous flight and what implications this will have on their daily lifestyles.

Research Questions

The following research questions were addressed by interviewing 15 commercial airline pilots' perceptions in Part 121 U.S. airline companies:

> RQ1: What are commercial airline pilots' perceptions of how the implementation of fully automated flight decks will affect the workload, training, and scheduling of commercial airline pilots?
>
> RQ2: What are commercial airline pilots' perceptions of how pilots will respond psychologically to the advancement of an automated flight deck and its effects on the U.S. airline industry?

RQ3: From a commercial airline pilot's perspective, how will the advancement of a fully autonomous flight deck affect the mindset of U.S. airline passengers?

Significance of the Study

Through the advancement of automation within the U.S. airline industry, the Federal Aviation Administration (FAA) has structured a new training regimen to help implement new automated systems that require workload, training, assignments, maintenance, responsibilities, and human resources for pilot training (Federal Aviation Administration, 2022). This advancement in policies results in an extended awareness of pilot training with automated systems and forces the U.S. airline industry to respond accordingly when tragedy strikes regarding automation malfunctions. Extended envelope training refers to the maneuvers and procedures conducted in a full flight simulator that go beyond the aircraft's limits of flight. Training for 14 CFR Part 121.423 - Pilots: Extended Envelope states that each certificate holder must conduct the approved extended envelope training in a full flight simulator to recover from loss or reliable airspeeds manually, slow flight, upset recovery maneuvers, bounced landings, and controlled instrument departure and arrival procedures (Federal Aviation Administration, 2020). This research study is significant because it has the potential to answer why this extended envelope training is required for airline pilots to override fully automated systems and the critical role U.S. pilots play in building confidence for fully automated commercial flights.

Another significance of this study is the psychological response of the pilots as the industry shifts toward fully automated flight. Many pilots choose this career path for the allure of adventure that is tied to their job description. However, how will pilots respond to flying a desk rather than flying the skies? A single-pilot cockpit is the next logical step in the road to total autonomy for commercial airline flights. This could save airlines as much as $60 billion annually in operational costs (Wyman, 2017). This emptying of the cockpit comes at a cost as pilots continue to juggle a redefined job description, role, and identity. From the passenger's perspective, pilots are the embodiment of trust with a responsibility to keep passengers and crew safe (Shahidi, 2019). People love stories of the heroic nature of pilots who turn a potential tragedy into a moment of triumph (Wyman, 2017). What happens to this comfort of trust as pilots move from reacting and responding to the aircraft in real-time from the cockpit to monitoring automation from a ground control center?

Limitations and Assumptions

Limitations for this study include any shortcomings or flawed methodology that impacts or influences the interpretation of the results. This can be a result of a lack of resources or limited information available for data collection. Every study, including this one, is not exempt from limitations that hinder and provide constraints to the methodology process (Sharpes, 2015). Assumptions provide another threat to the validity of data collection. Assumptions are defined as any influences the researcher has on any unexamined beliefs that we think without realizing it (Ekstrom, 2021). To eliminate both limitations and assumptions, delimitations are set in place to create boundaries for the research process. Delimitations help limit variables and guide choices for variables at play. For this study, the following limitations and assumptions were expected:

1. This study was restricted to the voluntary participation of commercial airline pilots to complete a qualitative interview.

2. The nature of the qualitative study was based on the pilot's personal experience and opinion on the implementation of a fully automated flight deck. These responses contained biases and subjectivity based on personal experience with airline procedures, company training, and personal exposure to automated systems.
3. It was assumed that each pilot would answer honestly and truthfully to the best of their knowledge on the set of questions asked when participating in the interview.
4. This study was limited to full-time pilots employed with a major U.S. airline operating under FAA Part 121 scheduled air service operations.

Literature Review

The Future of Aviation and the Increases in Automation

Do airline passengers know how much of a commercial flight is already automated? Chances are slim if passengers think pilots hand fly more than ten minutes each flight. On a Boeing 737, the primary airframe of Southwest Airlines, the dual autopilot system can be engaged 1,000 feet above the ground on takeoff and can land itself until all three landing gears are on the ground (ATP, 2016). Yes, the airplane can land itself; however, a research study conducted by John Cox, former US Airways Airline Captain, concluded that on an average 3,000-mile flight, the autopilot remains on over 90% of the flight with the exception of takeoff and just before landing, (Cox, 2014). Aviation faculty at Embry Riddle Aeronautical University (ERAU) expect fully autonomous flights to be common within the next few decades, starting with smaller private or air taxi companies (Rice & Winter, 2019). Both challenge companies and customers to reevaluate the risks and benefits associated with the advancement in automation technology. One must consider the safety, financial, and emotional hurdles needed to overcome the insecurities associated with fully autonomous aircraft for this inevitable future to happen (Rice & Winter, 2019).

Recent U.S. Major Airline Crashes Contributing to Automation Fear

The industry's support for the automation of airline manufacturers generates competitive pressure for companies such as Boeing and Airbus to perform at accelerated rates. Boeing's solution to this pressure resulted in the most tragic reality and possibly the greatest corporate disaster of the 21st Century: the 737 Max. After the tragic events of Lion Air Flight 610 and Ethiopian Airlines Flight 302, people have begun to think about how much of their commercial airline travel is controlled by automation rather than the pilot. Aside from the recent tragedy of flights 610 and 302 concerning the 737 MAX, other tragedies with automation malfunctions still linger within the aviation industry. Human error remains the leading cause of aircraft accidents (Federal Aviation Administration, 2022). An example of this unfortunate reality occurred on Asiana Flight 214 on July 6, 2013. This Boeing 777 was visually descending into San Francisco when the flight crew unintentionally deactivated the automatic airspeed control system and failed to monitor the airspeed to remain on a glide path (Gawron, 2019). This error resulted in a delayed action to initiate a go-around, causing Flight 214 to crash before reaching the runway threshold, killing three people on board. Factors contributing to this accident included (1) the pilot's inadequate training on visual approach procedures, (2) complexities with the flight director and autothrottle systems and lack of pilot training, (3) inadequate documentation of

these systems stated in Boeing's Asiana pilot training procedures, (Gawron, 2019). The FAA Human Factors Team Report (1996) reiterates these major categories of problems as the lack of mode awareness factors correlates to two-thirds of automation accident/incident reports (Gawron, 2019).

Psychological Aspects of Automation

Pilots are unlikely to use a system they do not trust. This narrative that humans and machines work, in contrast, needs to be broken for automation's advancement to occur. The perception that machines control humans gives automation a reputation of being happy and devoted to commanding the airframe toward its calamity (Mosier & Skitka, 1996), bringing 200-plus passengers along with it. This can result from automation bias through omission and commission errors resulting in the lack of intervention of pilots to erroneous automation data (Mosier & Skitka, 1996). The narrative analysis discussed in the Prahl et al. (2022) discussion post argues the same, stating that the only way to improve the reliance on automation is to eliminate human interaction. Here, it is argued that trying to make new pilots like old pilots is an expensive step, not just in monetary value but a costly decision for the safety and future of where automation is heading (Prahl et al., 2022). Humans are too unpredictable. This reality plays a heavy psychological factor in what the role of pilots will look like soon if that role still exists.

Current Success of Fully Automated Flight

Anthony Spencer, senior director of UAV & Unmanned Traffic Management at satellite giant Inmarsat, believes that by 2030, there will be over 10 million uncrewed vehicles flying in all spaces across the globe (Middleton, 2022). This future prediction is already a reality for private San Francisco-based company, XWing, as they conducted their first fully autonomous gate-to-gate cargo flight in 2021(Wolfsteller, 2021). While XWing successfully conducted its first hands-off flight with obstacle avoidance on both ground and air operations, the company is aware that the public has not yet been convinced that fully autonomous travel is trusted (Wolfsteller, 2021). Therefore, they will target the cargo feeder market while recognizing that proper pilot training in fully automated aircraft will be the key factor in getting the public onboard with pilotless travel.

Pilot Concerns Regarding Fully Automated Airliners

Regarding a study focusing on human factors concerns of UAV flight, one of the main consequences of the separation between aircraft and operator is the pilot's lack of sensory cues that help enable the pilot to interact with his or her environment. These sensory cues that are lost include kinesthetic/vestibular input, sounds of engine thrust, ambient visual information, and onboard sensory predictions, all of which can lead to the pilot operating in sensory isolation (McCarley & Wickens, 2012). Another major concern is the crew composition, coordination, selection, and training within the human factors-related issues regarding fully autonomous flight operations. Military reconnaissance missions currently operate with two pilots, one controlling the payload sensor controls, while the other is responsible for the airframe control and performance (McCarley & Wickens, 2012). If airlines continue to find ways to cut costs by

eliminating the number of operating pilots, this could lead to an alarming perpetual work overload for pilots in the future.

Passengers' Acceptance of Fully Automated Aircraft

The ERAU study conducted by Rice and Winter (2019) identified that 30% of U.S. airline customers would be willing to fly on an autonomous aircraft with no pilot on board. Of this 30%, many were eager to fly air taxis and be the pioneers to show that this is possible for a safe means of transportation. However, most of the public is not ready for this trust in automation due to their lack of knowledge of automated systems. Some do not know that pilots only fly the aircraft between three to six minutes during the entire flight (Rice & Winter, 2019). A 2021 study explicitly targeted how consumers view advanced air mobility (AAM), including air taxis and cargo-delivery drones. This was an ambitious task, as they were asking people about a service that did not yet exist and involved a theoretical scenario that had not yet been marketed to the public. However, their research findings prove necessary discernment about the customers' psychology of placing their lives in the hands of machines (Kloss & Riedel, 2021). The survey population was approximately 4,800 customers from areas across the globe, including the United States, India, Brazil, China, Germany, and Poland. Across the board, commuting and running errands were the top reasons to adopt this AAM service, except in the United States. Here, business took the lead, with 26% of participants in the United States stating they would switch to an AAM vehicle for the convenience of business travel and short-distance leisure trips (Kloss & Riedel, 2021). Although this qualitative study offered an awareness of customer acceptance of the theoretical AAM service, the main concern among all countries was the safety of these vehicles. 60% of respondents stated they have concerns about flying in non-piloted small aircraft (Kloss & Riedel, 2021).

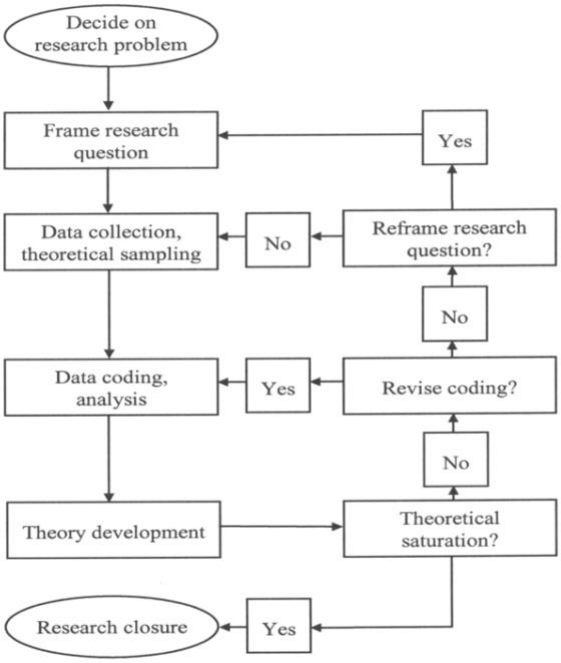
Industry Willingness of Autonomous Airliners

U.S. airlines and aircraft manufacturers say they would save money if they could reduce the number of qualified pilots flying the line. The status of the pilot shortage is another talking point for manufacturers to redesign the front of the aircraft, saving space for more seats available for sale, which is enticing for air carriers (Rice & Winter, 2019). A significant benefit of fully autonomous aircraft is the workload management for pilots. Allowing the FMS systems to lower the manual labor for pilots reduces operating costs, increases situational awareness, and increases efficiency, which seems to be the golden word in the airline industry. This increase in efficiency, in return, lowers ticket prices, increases customer loyalty, and generates greater profit margins for airlines (Beresnevicius, 2019). Airlines' goal is fully autonomous flight (Bochard & Baggioni, 2017). This is an alarming statement to pilots as the reduction of personnel drops fuel consumption by six percent, reduces the space needed for cockpit operations, lowers the price tag for manufacturing commercial aircraft, and increases the flexibility of pilot scheduling. Computers do not need to adhere to sleep and rest regulations (Bochard & Baggioni 2017).

Methodology

Investigational in composition, this research study identified the commercial pilot's professional perspective of an *unmanned flight deck*. This research design primarily followed the Grounded Theory (Glaser & Strauss, 1967) methodology. According to Glaser and Strauss (1967), grounded theory is reached through the discovery of theoretical functions of research. Grounded Theory is developed from inductive theories that are grounded on the systematic data analyzed for this specific study (Figure 1) (Bitsch, 2005).

Figure 1
Grounded Theory Methodology



The Theoretical Sensitivity (Glaser, 1978) approach, which reflects the potential for data to be analyzed in theoretical terms, is integrated with what is already known about automation in airline operations while further developing the interaction between fully autonomous flight and the commercial pilot. Asking pilots about this theoretical scenario offers its own challenges to expand the imagination. However, pilots are already no strangers to the automation that exists in their everyday lives flying commercial aircraft. The semi-structured qualitative research consisted of developing a deeper understanding of the pilots' thoughts on the three-pronged approach: (1) the psychological barriers and motives of the pilot, (2) the differences in aircraft ground-based safety and training, and (3) pilots' understanding of the timeliness of entry for unmanned flight deck operations to reach FAA standards.

Sample Population

Commercial airline pilots, including ranks of both Captains and First Officers (FO) in Part 121 scheduled service, were the research population for this study. The sample population

number was 15 airline pilots offering various diversity in age, gender, years of service, airline employer, and military or civilian flight experience. Gaining content comparison between the relationship and patterns in variations of the data, the sample reflected key individuals who identified as having significant professional knowledge (Patton, 2015).

The non-random sampling method used by the researchers was both purposive and convenient. In purposive sampling, the researcher selects participants who have the needed qualities of subject knowledge and topic understanding (Gay & Airasian, 2003). Convenience sampling indicates the selection of participants based on group availability (Gay & Airasian, 2003). The researchers established limits on participants to only those currently employed as U.S. commercial airline pilots, suggesting a purposive sampling process. The researchers also took advantage of selecting participants from personal contacts within the airline industry and referrals from other industry professionals, suggesting a convenience sampling process.

Research Instrument and Data Analyses

The collection of research data began by contacting U.S. certificated Part 121 airline pilots and asking for their willingness to participate in a research study involving their professional insight on the future development of aircraft automation within the airline industry. (Appendix). Regarding the interview process, the researchers asked several demographic questions to better understand the pilot's employment position and responsibilities with the specific airline. Next, the researchers asked a series of open-ended questions to develop a deeper understanding of the pilot's willingness to adopt fully autonomous aircraft and the amount of automation they are currently using in the cockpit. The last part of the interview process allowed the pilots to provide additional personal and professional comments regarding the future of autonomous commercial airline flights. These ten questions drove the initial conversation; however, the pilot was provided the freedom to diverge into other perspectives. Rather than taking notes, all interviews were audio recorded and transcribed by the researchers to ensure consistent data. These transcripts were generated through Zoom's formalized transcription process, and then the researchers used inductive coding to manually code each transcript and cluster common responses into themes (Creswell & Creswell, 2018). The collection of data began in November 2022 and concluded in January 2023.

Validity and Reliability

The validity of the research instrument was assured by forwarding interview questions to airline professionals representing the commercial aviation environment, as well as aviation faculty members knowledgeable of the U.S. airline industry and qualitative research methods (Robson, 2002). These nine aviation professionals and faculty members examined the set of questions, confirmed its focus on the research topic, and verified its clarity in wording and instruction. To ensure interview reliability, all questions were consistent across the administration of the interview and were asked the same way by the researchers. Also, the researchers summarized and restated the findings gathered from the interview and allowed the pilot to reflect on any additional feelings, views, or experiences regarding the responses shared with the researcher (Robson, 2022). This increased the authenticity of the findings and decreased any incorrect interpretation of the data.

Research Findings

The research findings were derived from interview data, which was transcribed and examined to develop themes related to each of the three research questions. Demographics of the fifteen participating pilots are displayed in Table 1.

Table 1
Demographic of Participants

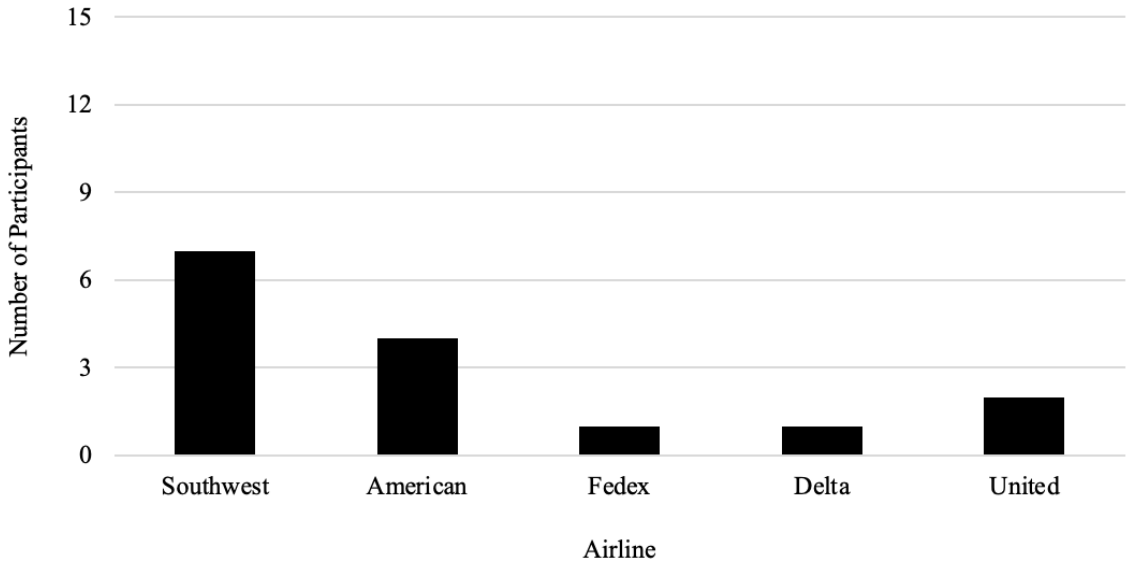
	Employer	Gender	Military Background	Rank	Years of Service
Pilot 1	Southwest	Male	Yes	Captain	32
Pilot 2	American	Female	Yes	Captain	22
Pilot 3	FedEx	Male	Yes	Captain	22
Pilot 4	Southwest	Female	No	Captain	24
Pilot 5	American	Male	No	Captain	35
Pilot 6	United	Male	No	First Officer	7
Pilot 7	Southwest	Male	No	First Officer	1
Pilot 8	Southwest	Male	No	Captain	30
Pilot 9	Southwest	Male	No	First Officer	9
Pilot 10	Southwest	Female	No	Captain	34
Pilot 11	United	Male	No	First Officer	4
Pilot 12	Delta	Male	Yes	First Officer	3
Pilot 13	American	Male	No	Captain	32
Pilot 14	Southwest	Male	No	First Officer	6
Pilot 15	American	Male	No	First Officer	26

Data Analysis of Interview Questions

(Q1) What is your professional flight background and current position as an airline pilot?

Figure 2 displays the employer demographic. The 15 pilots are represented across five U.S. airline employers. Within the interviewed group of pilots, seven (47%) were Southwest pilots, four (26%) were American pilots, two (13%) were United pilots, one (7%) was a FedEx pilot, and one (7%) was a Delta pilot.

Figure 2
Employer of Pilots



Of the 15 interviewed pilots, 12 pilots (80%) were male, and the remaining three pilots (20%) were female. Four of the pilots (27%) indicated they had served in the military, whereas 11 pilots (73%) indicated they did not have a military service background. Each participating pilot was asked about the current professional rank. Eight of the pilots (53%) were Captains, and the remaining seven pilots (47%) were First Officers. Last, three pilots (20%) had five or fewer years of service, three additional pilots (20%) had between 6-10 years of service, three pilots (20%) stated they had between 21-25 years of service, two pilots (13%) had between 26-30 years of service, and the remaining four pilots (26%) had between 31-35 years of service.

(Q2) From your experience as an airline pilot, do you believe passengers are aware of how much flight deck automation currently exists within commercial flights?

Although 80% of respondents believed that passengers are aware of how much automation exists, a common theme between responses was the lack of a passenger's understanding of automation levels that pilots encounter during flight. Pilot 2 believed that passengers are overly aware of how much automation currently exists, "They think we have more automation than we do because I get comments all the time like, 'Well, you do not really do anything. The autopilot does everything. You just sit there.'" Pilot 5 agreed, "I think there's a perception that we don't do anything out there. We just watch it fly."

The pilots who responded no to this question were consistent in their responses regarding automation. A commonality amongst this group of pilots was that passengers have a sense of awareness of automation within a commercial airplane but do not have a full understanding of the degree to which it exists. Pilot 1 stated, "I think some passengers are probably surprised at how much the autopilot flies the airplane. People know there are some phases of flight that require automation, but probably have no idea the purpose behind the automation." Pilot 6 felt similarly, "The public thinks that an autopilot in their Tesla car is the same as using an autopilot

in an aircraft. They assume that we input a destination airport, and the plane magically takes off and flies us to our destination while we sit there and wait in case of an emergency."

(Q3) What will be some of your personal and/or professional benefits (if any) with integrating complete automation into commercial flight?

When asked to consider the benefits of complete automation in the industry, the pilots had similar responses. As a result, several themes emerged from the pilots' perceptions regarding the benefits of complete flight automation. The themes were (1) better home life, (2) personal safety, (3) minimizing fatigue, and (4) regular schedule.

Most pilots (73%) stated, at some level, that their home life would improve if they were able to fly fully autonomously. Pilot 9 described this benefit as such, "The benefit would be to be home every night. I would say the biggest resource that we provide to our companies is our time. And that is why sometimes I do not feel guilty about making the money that we do because I am missing time with my kids." Pilot 4 compared pilots to their friends who have a more standard work-life balance. "I think the comfort factor would be very appealing for pilots. You would have to look at it if you were the one traveling on the road, away from family, and missing day-to-day events that other people with 9-5 jobs get to go to."

Sixty percent of the pilots who identified personal safety as a benefit based their opinion on less exposure to radiation. Pilot 13 described his relationship with radiation exposure as this, "On the 777, you get a lot of radiation exposure. When you fly in the high latitudes, the higher north you go, and depending on the solar activity, the more radiation you get. So, a lot of people on the 777, which is highly automated, efficient, and can get up to these altitudes very quickly, get a lot of radiation."

Almost half of the pilots (47%) responded that minimizing fatigue and time zone changes would be a significant benefit. This is not surprising as seven of the 15 participants frequently fly internationally. Pilot 10 states, "Well, I would not have to travel through so many time zones to do my job, which sounds amazing." Pilot 8 combines a lack of fatigue and more home time into his response. "I think fatigue for sure. It is a big thing. Pilots are gone a lot. I like being home. The perk of flying allows you to experience a lot of things, but at the end of the day, I like being at home."

Three pilots mentioned a benefit of flying fully autonomous aircraft would be having a more regular schedule. Many of these responses were paired with having better sleep patterns, less task saturation, and boredom within the job. Pilot 15 correlates a more regular schedule when talking about flight delays and cancellations. "You would have more of an 8 to 5 schedule. When your shift is over, you are done." Pilot 13 agrees: "You have a set schedule to fly autonomously at some facility, and then you just go home. I would get more time with my family."

(Q4) What are some of your personal and/or professional concerns with integrating complete automation into commercial flight?

When the researchers asked the participants what concerns they may have with complete flight automation, several themes emerged, including (1) trust in automation, (2) task saturation, (3) communication gap, (4) software failure, (5) lack of aircraft control, and (6) terrorism.

Lack of trust in automation was a common response, as 47% of pilots addressed this as a primary issue when discussing the concerns with implementing fully autonomous flight. Pilot 1 stated, "I do not think people will trust it. I do not think that you are going to find many people who would be willing to get on an airplane where there is not a human flying the aircraft." Pilot 13 had similar thoughts on the issue. "If I am down on the ground flying and they are up there, I would always worry about that link and pray not to lose connection or get hacked. I do not trust the overall safety of the whole thing." Pilot 1 commented on the lack of trust from the passengers' perspective. "There is a level of trust in pilots because passengers know they are not going to do anything that will put their own life in danger. Whereas if a pilot is not actually sitting in the cockpit, where is that level of trust placed now? I am not saying that somebody who is flying an airplane remotely would purposely be nefarious about it. However, the truth is people will not trust automation."

Pilot 2 felt strongly about the concern of task saturation. Having military experience, she worked with many drone pilots who experienced task saturation and boredom. "For me, sitting in a box would be boredom. This would be the silent killer." Task saturation was the outlier, as only one pilot spoke of this concern.

Forty percent of pilots addressed the communication gap as a concern with fully autonomous flight. Pilot 3 questioned the integrity of an autonomous system and his ability to override the automation if needed. "How will I communicate with ground operations? There are so many fail-safes with us being up in the sky, but what happens when something goes wrong? There must be safety nets in place because something is going to happen. It is only a matter of time." Pilot 2 linked the communication gap to the lack of sensory cues present in the box rather than physically being in the cockpit. "You do not have the ability to hear what is going on in the cockpit. You do not have the ability to smell an electrical fire." Pilot 2 posed the question of what happens when a pilot flying the box gets multiple emergencies at the same time. "How do you prioritize? Deciphering the emergency is hard enough being in the cockpit. If you cannot see or touch it or have somebody that is there to tell you what is going on, then how do you know what to do?"

Sixty percent of the pilot group expressed their concerns about software failures. Pilot 4 stated, "We all see problems with automation, computers, and software failures. If you had a software failure, it could cancel communication between the pilot and the automation itself." Pilot 6 added, "My biggest concern is the divergence of two factors that make air travel unsafe: implementing more automation and deteriorating pilot skills. If I am not up there, and I do not see it, how can I react to certain things? Pilots are trained to think ahead, and the computer cannot see things like that right now within the cockpit."

Sixty percent of pilots expressed the inability to physically control the aircraft as a major concern. Pilot 6 gave this scenario, "A lot of times, the controller gives me speed 180, and I can tell the computer is not adjusting for the differing winds. If I do not intervene, I am going to eat

up the guy ahead of me." Pilot 7 added, "If something was to go wrong, then who is there to take over? Fully automated aircraft are a man-made product, and everything that is man-made fails."

Only 13% of participating pilots mentioned the threat of terrorism as a concern for fully autonomous flight. Pilot 7 questions the thought of terrorism if fully autonomous flight is achievable. "We have a locked cockpit door with two pilots up front that have control of the airplane. Who would want to trade anything for that? Whereas, if it is a Wi-Fi based or satellite-based system, anybody could hack into that system and technically override that aircraft and use it for a terrorist attack."

(Q5) What are your thoughts on losing the adventure of travel and the joy of flying?

Only one of the 15 pilots (7%) was good with this proposed change to their career expectations, with Pilot 9 stating, "This is going to sound horrible. I am not at the place in my career where I necessarily come to work for the fun aspect of it. I am in this growing family phase, so it is more important for me to be at home for longer times. Right now, I come to work to make money, and then I go home. So, I do my best to maximize my pay on the road, and then I get the heck out there."

While only one pilot saw losing the travel aspect of the job as a positive, 93% of pilots would miss the travel. Pilot 1 felt strongly about this issue, "I could not do the drone pilot thing. Sitting and learning in a little box, not actually flying around, and seeing new things does not entice me." Pilot 8 stated it this way, "I would hate it. It is a big reason pilots get into this industry because it is different from a 9 to 5 job. You are not sitting at a desk. You actually get to go out, see things, travel, and fly."

(Q6) From an airline company perspective, what are some of the benefits of moving toward complete automation? What are the threats and risks of complete automation?

When responding to question six, the pilots addressed three key factors of why the move toward fully autonomous aircraft would be a benefit from the airline's perspective. The three factors were (1) cost savings, (2) pilot fatigue, and (4) human error.

Of participating pilots, 87% stated that cost savings would be a huge attraction for airlines to move toward fully autonomous aircraft. This cost-saving would come from a reduction of fatigue and sick calls, pilot salaries, travel expenses, contract negotiations, and other ancillary costs required to operate an airline. Pilot 12 commented, "From a corporate perspective, you could make the case for more efficiency and cost savings because employees are the most expensive part of the system." Pilot 13 viewed this similarly, "I think they would save costs. They would not have those darn expensive pilots and would not have to negotiate contracts with them or pay health care costs."

Pilot 11 believed the lack of pilot fatigue, from a scheduling standpoint, was a major benefit from a company perspective. "A big benefit would be fatigue. If we were completely automated, that would take the human fatigue element out of it. And then, if we became systems

monitors, our schedules would rotate from shift to shift every six hours. Then we are done for the day."

Twenty percent of pilots agreed human error would be a major concern when discussing safety amongst pilot operations. Pilot 6 had recently completed FAA training known as Pilot Professional Development (PPD), where each employee learns about his or her personality and characteristics and who they might work well within this environment. Pilot 6 saw this as a major benefit between the human-to-human interaction that causes friction within the workforce. "So that is eliminated, too, right? I do not have a 64-year-old pilot paired with a 24-year-old pilot and trying to mash two generations together. Or a grumpy pilot who just went through a divorce and does not want to engage with the other pilot. That does not work well, so that is all eliminated, which is a huge benefit for the airline."

The second part of question 6 asked the pilots to respond to threats and risks of complete automation from an airline's perspective. The researchers identified four themes based on the pilots' responses. These themes were (1) the public is not ready, (2) increased risk in operations, (4) cost of technology, and (5) terrorism.

Forty percent of pilots agreed that the public is not ready to move toward complete automation regarding airline profitability. Pilot 14 stated, "I personally do not think passengers will ever trust fully autonomous airplanes." Pilot 15 also recognized the reputation that US airlines must uphold in the future. "You know the U.S. has one of the best safety records for FAA regulations, and overall, we have done a good job of safely moving people from A to B. I do not know if the integration of autonomous flight is worth that reputation from an airline perspective."

Of the 15 pilots, five (33%) mentioned the increased risk in flight operations as a concern. Pilot 6 commented, "There would be huge operational risks from a company perspective." Pilot 13 described a scenario based on a passenger having a heart attack onboard and how the increased risk of not having a pilot in the cockpit could possibly result in loss of life without human intervention to divert the flight plan.

Twenty percent of participants identified the cost of technology as a barrier. With reduced overall costs being a benefit, Pilot 9 addressed the duality of the cost-benefit analysis many airlines would undergo to achieve complete automation. "I do not think it is enough of a cost-benefit to recoup the huge undertaking and investment that it would take to make complete automation a possibility. I think it would take decades to earn back the investment dollars. And I do not know if airline management is into getting returns on investments that would take that long."

While Pilot 4 was the only participant to identify the threat of terrorism as a risk of automation, she viewed this as an issue that supersedes any potential benefits, "You know I still have a major fear of terrorism. You have always been cautious of that. I think if pilots were all ground-based, it opens a new different level of terrorism and is not even worth talking about the cost-effectiveness that the company could be saving."

(Q7) What are your professional concerns about the employment of future pilot hiring? What will it take to get an entire customer base to trust automation?

Two-thirds of pilots (67%) did not find any concern regarding the future of pilot hiring. Pilot 9 used the current pilot shortage as part of his justification, stating, "With the current pilot shortage, I am not concerned about losing my job yet. We have not raised the pay enough to make it even a desired position." Six pilots from this grouping stated their lack of concern for the future of pilot hiring stemmed from their doubt that fully autonomous flight would come to fruition within the near future. Pilot 2 remarked, "I do not think it will happen in the next 20 years, maybe in 30 years. But as for my employment, I am not worried."

Three pilots (20%) addressed the accelerated hiring process within their airline operations and how this is a direct path to a shortage of proficient pilots in the future. Pilot 13 explained, "A lot of the pilots that we are getting, especially on the automated Airbus, lose their stick and rudder skills. They do not really know how the aircraft works. You are just a manager of automation, and you are following the pink line. There is a real concern about pilots losing stick and rudder skills and the knowledge of flying."

Pilot 8 mentioned another concern is the lack of pilot proficiency in relation to pilot overreliance on automation. "Today, you can start at zero flight time and in four years be hired at Southwest. The lack of experience out there with actual real life and knowledge on issues is quite scary, and I see it all the time. From a human decision-making standpoint coupled with a fully autonomous world, this could be a recipe for disaster. If the computer is deciding for you, and you, as a pilot, have never been in a similar emergency, then I do not see any good outcomes from the situation."

The second part of question 7 asked the pilots what it would take for the customer base to trust automation. The researchers identified three themes based on the pilots' comments. The themes are (1) data evidence, (2) perception of safety, and (3) advanced technology.

Sixty percent of the pilots agreed that data evidence would help build consumer trust. Pilot 3 commented, "For customer trust, I think they would require a whole lot of data regarding successful flights." In addition, two-thirds of this pilot group mentioned that cargo aircraft would be the first to help build data evidence for passengers. Pilot 14 stated, "I do not think trust is impossible. I think over time it will happen, but it will have to occur in areas like cargo first and then go to one pilot in the cockpit."

About one-half of the pilots (53%) mentioned the increased perception of safety as an avenue to build consumer trust. Safety perception built through regulatory bodies such as the FAA and ICAO supports this theory as Pilot 10 felt confident about her opinion, "I would say there needs to be a lot of data and a lot of demonstrations as to what safety really is. Regulatory bodies like the FAA and ICAO would have to come together and establish standards in place to ensure this will work the way it is intended to work for the level of safety needed."

One-third of the pilots stated if there was an increase in better technology, then public trust would increase as well. Pilot 8 commented, "We need technology that thinks and acts not only like computers but as humans." Pilot 14 also saw the need for additional technological improvements as he compared the technological differences between Boeing and Airbus aircraft. "You look at the 737, and you compare it to an Airbus. The 737 is old, and it has not gotten any newer. The 737 is being marketed as a new airplane, but it still uses 1960s technology. So that means that everything the airplane does with hydraulics, air systems, or electrical systems demands human intervention. But for Airbus, they see rapid technological growth. There are only like four buttons in that airplane, now."

(Q8) Do you believe that the human element of aeronautical decision-making will always mitigate risks and threats better than a computer?

An overwhelming 87% of pilots thought the human element within aeronautical decision-making would mitigate risk better than a computer. Pilot 1 added, "I do. I was just in a briefing the other day, and we talked about the concept of risk. Risk has no memory. So, just because you got away with something one time does not mean that your risk of an unwanted outcome is any less because you have seen it before. Also, we can never truly replicate all the exact conditions every single time that we do something. Whether it be flying an airplane or riding a bike, you are never going to exactly replicate everything. So, I believe that a human has a better propensity to help reduce that risk than a machine does. Machines try to replicate; humans try to investigate."

However, pilot 7 believed computers could mitigate risk better than the human element. "You have done your accident investigations just like I have, and many of them are human error. However, I will say there have been a lot of automation failures where humans had to take over and save an accident. I do not think that computers are smarter than humans, but I do not think that humans are necessarily smarter than computers. They both have their own defined roles."

(Q9) Would you choose a commercial airline pilot career path if you knew you were to fly a desk rather than flying the skies? Why or why not?

Only 20% of pilots would consider an airline pilot career as a remote pilot rather than physically flying the aircraft. Pilot 6 responded, "I would still choose it. With the increasing global population and more people rising out of poverty, there is a good chance we will have more flights requiring more pilots. So even if we reduce the number of pilots on the flight deck, we will need more individual pilots for the ever-increasing number of flights."

The remaining 80% of pilots would choose a different career path if they knew they were going to sit at a desk rather than sitting in a cockpit. Pilot 1 responded. "No, I would not do it. It would not be the same job anymore." Pilot 7 also commented similarly, "I would probably change careers. I could not sit at a desk. That is the reason I got into aviation, to begin with. Being confined to a cube or a building all the time is not something that I am wired for." Furthermore, Pilot 10 stated, "No, it does not sound appealing to sit inside and operate a video game type control room. There is no longer a human element." Last, Pilot 14 would choose a different career as well. He simply stated, "There is just something special about flying an airplane."

(Q10) As an airline pilot, do you believe you will have the opportunity to experience a fully autonomous flight before your mandatory retirement age? Why or why not?

Despite their years of service, none of the pilots believed they would see fully autonomous operations before their mandatory retirement age. Pilot 2 said, "I hope not. I could be wrong, but I do not think we are there yet. If anything, air traffic control (ATC) will go autonomous before we do. There is a feature on the Airbus that allows us to communicate with ATC in a way like texting rather than talking on the radio. They type it in, it shows up, I accept it, and it gives me a new altitude. I go to the control panel, accept the altitude, and the aircraft climbs." Pilot 10 mentioned the Boeing 737 MAX incidents as examples of why fully autonomous flight will not be achieved within her commercial career. "Just like in the B737 MAX crashes, systems failed, but the pilots had a fighting chance to bring the airplanes down safely. If a complete automation system fails, who is there to take over?"

Conclusions

Conclusions Based on Research Question One

As automation continues to advance within the aviation industry, the workload, training, and scheduling of pilots will begin to look different. The findings based on research question one are (1) the role of the pilot changes from a single flight focus to a multi-flight monitor, (2) the demand for a pilot's stick and rudder skills will continue to diminish overtime, (3) there is a heightened sense of pilot awareness while physically flying the aircraft, and (4) pilots desire a better work-life balance.

The findings concluded that pilots are aware of the workload changes that are present with implementing fully autonomous aircraft in the Part 121 category. Two themes became evident when discussing workload changes. First, the role of the pilot changes from a single flight focus to a multi-flight monitor. As a result of airline cost savings, 87% of the pilots believed this would be a benefit for airline operations in the future. Pilots will pass along workload responsibilities rather than assuming full responsibility for each flight. Secondly, as technology advances, the pilot's physical workload of hand flying an aircraft will constantly deteriorate. Therefore, the demand for a pilot's stick and rudder skills will continue to diminish over time. According to the participating pilots, the aircraft's autopilot is engaged, on average, between 95-99% of scheduled flight time. While it is no secret that the public knows automation exists within the airline industry, only a small percentage have knowledge of the various levels of automation capabilities and their purpose during different phases of flight.

The term having *skin in the game* was mentioned by several pilots as they believed their sense of awareness was heightened while physically flying the aircraft rather than being in a simulated environment during training exercises. This was evident when the participating pilots stated the removal of sensory cues was a professional concern. Would pilots still get the same sense of adrenaline or ownership if they were sitting in a box? Training pilots for situations in which they might not have control will create a major difference in situational management,

having to understand how to override automation failures without humans physically being in the cockpit. This was a concern for 60% percent of the participating pilots.

The most predominant theme when discussing scheduling changes was the pilot's desire to be at home. This was significant as 73% of the pilots mentioned that a better home life would be a benefit in moving toward a completely autonomous industry. This was discussed through the benefits of less time commuting, less time spent in airports, less task saturation, less boredom, and less fatigue specifically related to long workdays or time zone differences.
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Conclusions Based on Research Question Two

The advancement of a fully automated flight deck and its effects on the U.S. airline industry can potentially have significant impacts on the psychology of commercial airline pilots. While pilot responses varied based on individual experiences, attitudes, and adaptability, there were several psychological responses identified in this study, including (1) loss of control, (2) uncertainty toward technology, (3) job insecurity, and (4) adaptability.

Pilots who have spent countless years gaining expertise in manually operating an aircraft may experience a sense of loss of control in their job duties with fully autonomous flight. This loss of control could lead to feelings of frustration, anxiety, or a diminished sense of job fulfillment. This was evident as 60% of pilots addressed their lack of control over the aircraft as a professional and personal concern. Automation is eroding their ability to physically override the aircraft, which, naturally, pilots will be resistant to. Pilots may begin to feel their skill set is becoming more obsolete and, as a result, are being pushed out of their profession.

The introduction of automation increases technological uncertainty for pilots regarding the reliability, safety, and vulnerabilities of automation. As evidenced in the study, most pilots (87%) believed humans can mitigate risk better than computers. This demonstrates the clear uncertainty toward current automation systems that currently exist within the US airline industry. Should the ability of automation continue to improve, pilots may change the way they view computers to manage emergency situations effectively. For now, however, it is clear there is an entrenched view to favor human aeronautical decision-making.

Increased automation creates insecurities within the pilot profession. The role of airline pilots may change from being a primary operator of an aircraft to simply monitoring and supervising an automated system. This leads to pilots feeling less valued regarding their careers. If automation proves to be safe, dependable and trusted among passengers, the U.S. airline industry could witness an overall decrease in the demand for pilots. While 67% of the pilots expressed no concern regarding future hiring, this could become a reality should the risk and/or benefit of implementing automated systems change.

Change is inevitable, and all must remain adaptable in this profession. However, increased automation would significantly change the aviation industry, and pilots may struggle to adapt to new lifestyles and technologies. Most pilots are not willing to accept this new lifestyle, as evident in that 73% of the participating pilots would choose a different career if they were required to sit in a box rather than physically fly the aircraft.

Conclusions Based on Research Question Three

The advancement of a fully autonomous flight deck will obviously create additional concerns for U.S. airline passengers. The most significant concerns for passengers will include (1) safety, (2) trust, (3) passenger-pilot relationship, and (4) understanding of technology. Passengers will always question if modern technology has been thoroughly evaluated and if it can react to unexpected situations as safely and effectively as a human. Before any autonomous technology is mentioned as a permanent replacement within the cockpit of a commercial airliner, passengers must feel comfortable with the overall reliability and safety of this modern technology. If automated flights become more common and can provide convincing evidence regarding their reliability, then perhaps passengers will have more trust in autonomous technology. Some of the pilots participating in this study mentioned how passengers have come to trust the auto-pilot systems currently in use. And that passengers will need to view autonomous flight as the natural progression in technological advancement onboard commercial aircraft.

It is entirely possible that the absence of pilots on board will create differing views among passengers. Some will have more trepidation about being in an unfamiliar situation without the perceived safety of a human sitting in the cockpit. For others, they may feel safer flown by a computer and not having a human error element onboard. However, 80% of the participating pilots agreed the human element of intervention is safer than relying on unpredictable and unreliable automation. There is little doubt the relationship between the pilot and passenger will look completely different if fully autonomous flight is implemented.

Final Summary

The purpose of this qualitative study was to interview 15 airline pilots to identify their perception of an unmanned commercial flight deck and its intended implementation in the U.S. airline industry. The objective was to better comprehend fully autonomous flight and the influence it will have on U.S. commercial airline pilots, as well as investigating the effects on the U.S. airline industry and the human-machine interaction. This research, through the personal life experiences and professional knowledge of the participating pilots, along with existing research, was able to identify those elements needed to make conclusions for each of the three research questions.

This study succeeded in providing a greater knowledge of pilot perception toward automation and the impacts that fully autonomous flight will have on the role of a pilot. This study also provided a knowledge base on pilots' current lack of trust toward automation. Grasping this theoretical concept of fully autonomous flight within the airline industry was alarmingly foreign to the pilots participating in this study. This finding from this study will further educate the public and other pilots on the possible opportunities and obstacles with the integration of advanced technology in the cockpit.

Recommendations for Further Research

The findings from this study provided the opportunity for future research initiatives. Further research into current advancements in automation that exist specifically pertaining to flight operations would be beneficial in understanding current policies and regulations within FAA standards. Further research into Air Force drone operating units would assist in developing commercial standardization for fully autonomous flight in the airline industry. Although military drones are usually weaponized for combat and operate under different operating categories, a greater understanding of fail-safe procedures, training requirements, operating spaces, and communication between aircraft and ground-based systems would be beneficial.

Further research into the psychological element of human trust regarding automation would help articulate the complexities that seemed intangible to many of the pilots within this study. Automation was considered by many participants as just another tool used in the cockpit. How will automation go from being thought of as a tool to being dependent upon people's lives? Further research aimed at specific measures to gain public trust, other than from a pilot’s perspective, would assist in a more holistic approach to understanding the psychology behind how humans build trust.

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APPENDIX

Interview Questions

The following tentative interview questions will be asked to each participating pilot:

1. What is your professional flight background and current position as an airline pilot?
2. From your experience as an airline pilot, do you believe passengers are aware of how much flight deck automation currently exists within commercial flights?
3. What will be some of your personal benefits and/or professional (if any) when fully autonomous flight is in operation?
4. What are some of your personal and/or professional concerns with integrating complete automation into commercial flight?
5. What are your thoughts on losing the adventure of travel and joy of flying?
6. From an airline company perspective, what are some of the benefits of moving toward complete automation? What are the threats and risks of complete automation?
7. What are your concerns about employment for future pilot hiring? What will it take to get an entire customer base to trust automation?
8. Do you believe that the human element of aeronautical decision-making will always mitigate risks and threats better than a computer?
9. Would you choose this career path if you knew you would be monitoring a fully automated cockpit instead of piloting the aircraft? Why or why not?
10. Do you believe fully autonomous flight is achievable in your lifetime? Why or why not?