The Impact of UAS on the Passenger Airline Industry

Matthew Whitten

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Steven Brinly, M.S.
Thesis Chair

____
Jonathan Washburn, M.S.
Committee Member

____
James H. Nutter, D.A.
Honors Director

____
Date

Abstract

This study seeks to cover the state of modern autonomous unmanned aerial systems (UAS) integration into commercial aviation, the future applications of the technology in the airline industry, and the roadblocks currently hindering its integration into passenger operations. Although great advancements are being made in the field, technological developments, economic impact, legal restrictions, airline cost, and public perception stand in the way of the full adaptation of autonomous technology into everyday passenger operations. However, technology is rapidly developing, perhaps allowing for the possibility of autonomous air travel even today, but there are likely years of refinement before regulators, executives, and consumers adopt autonomous air travel into everyday life.

The Impact of UAS on the Passenger Airline Industry

Aircraft automation has been increasingly more prevalent within commercial and civil cockpits over the past several years, and technological advancement within aviation has been a constant field of development, with systems such as Elmer Sperry's first autopilots and the invention of steam gauge and glass aircraft instruments. However, modern technology has now brought us to perhaps the most notable advancement yet within aviation, unmanned aircraft technology (Barnhart et. al., 2016). Unmanned Aerial Systems (UAS) are not new inventions, and even date back to the early 20th century. However, more advanced UAS technology did not arrive until World War II with myriads of training devices, such as the Queen Bee target drone (Dalamagkidis, 2014). These trainers are not the most advanced devices, but they are useful for target practice. As time went on, more advanced versions of UAS technology begin to arrive. In Vietnam, high speed drones are used in different capacities to distract the enemies or even to fight, and in conflicts since the time of Vietnam, drones have become a staple in American warfare (Miller, 2013). Many of these devices are unmanned, but most of them still have a pilot remotely controlling the aircraft. These remote piloting capabilities are due to the technology available today, allowing aircraft to be piloted from thousands of miles away. However, as more advancements come in today's technology, an increasing amount of drone technologies and applications are being developed. Even though these military applications are remarkable, there is perhaps one area that best displays the advancements made in the commercial UAS field even more than combat, precision agriculture.

Precision agriculture refers to the advanced farming practices and systems used both on the ground and in air today, not specifically to UAS operations. However, drones can play a big role in this method of growing crops. Today, farmers and UAS operators have been using drones of various kinds to perform rudimentary tasks, such as mapping fields or even flying over crops and using advanced camera technology to search out problem areas for the farmers. However, one thing to note in these applications is that many of these drones are autonomous. The use of GPS technology, previously drawn flight paths, and location fencing allow this to be possible, leaving the operators to simply launch the device and recover it at the end of the job, making the process not only hands-free but quick. The drones can then be fitted with various cameras or scanning technologies to accomplish the goals of the farmers. Another technological advancement that has impacted this field is Wi-Fi. Nayyar et. al. (2017) states that "with the integration of Wi-Fi technology in drones in form of first-person View (FPV), drones can be integrated with HD cameras like GoPro, DJI, Parrot and many others to stream real-time video of flight over smartphone or tablet" (p. 508). This kind of uplink allows the farmers to see their fields live from the air. Not only do these technologies make farmers jobs more precise, but they also save them many hours and a lot of money in utilizing these methods.

Aerial agriculture is not new. From surveying companies to pesticide applicators, many farmers employ the use of airborne equipment to make their jobs quicker and easier. However, airplanes have many limitations that do not apply to their UAS counterparts. First, airplanes are not capable of flying in the same spot or flying at very slow speeds to capture a desired location. Thus, airplanes are much less capable than their UAS counterparts of surveying smaller pieces of land. Another clear and obvious benefit to the use of UAS is the cost savings involved. Not only is there no pilot required for these aircraft, but many of them are also powered by electricity, instead of AV gas. On the other hand, many of these electrically powered drones are limited to a smaller scale aircraft than large, perhaps passenger carrying aircraft, but as technology has adapted, more progress has been made towards electrifying larger aircraft. History was made in May of 2020 when an all-electric Cessna Caravan was safely flown, which was said to be the largest electric aircraft in the world (Ansell and Cinar, 2020). Having electric aircraft like these could provide remarkable savings, since no fuel is required. One study illustrates these savings well, by taking a normally gas-powered airplane and making it electric. In the end of the study, it was said that a 62-mile flight cost around $3.00, as opposed to the hundreds of dollars that it would cost for a gas-powered airplane to fly for the same duration (“Fly Electric”, n.d.). To apply this research to UAS technology, a much smaller drone would consume even less power, making the savings increase for farmers. Electric aircraft may be coming, but they are not here yet, and for now, small-scale UAS technologies are a much cheaper alternative to their airplane counterparts. Finally, GPS mapping technology allows for a much more precise route to be flown by the aircraft than a human pilot would be able to hand fly the airplane. These navigation capabilities allow the farmer to have an extremely efficient system in place, allowing him to ensure that the whole job is completed and in an efficient manner.

The benefits are clear with regards to the use of UAS technology within agriculture, but there are still some hurdles to its adaptation into larger commercial fields, such as the airlines. First, and perhaps most notably, UAS technology is primarily adopted mostly to small-scale applications. Although unmanned aerial vehicles (UAVs) have become a staple for many farmers around the globe, surveying fields is a rudimentary task, and while there is a lot of promise, there are still aviation companies who perform similar tasks on a large scale with manned aircraft. Much of this may be due to the legal restrictions placed on UAS flying, which will be discussed later. However, if the technology is to expand, there must be advancements that bring UAS technology beyond this type of simple flying to a commercial level. One area in which this is being done is within the cargo delivery industry. UAS technology is currently being tested by companies like Amazon to ascertain the capability and safety of these systems to deliver packages to individuals in residential and corporate contexts (Behdinan and Perreault, 2021). These drones are allowed to fly over residential and even urban areas to deliver their goods, and they may be the first real picture of what wide-spread autonomous aircraft may look like in the public sector. These aircraft can fly from point A to point B quickly and with reduced human intervention throughout the entire process. Although, the technology is still in testing and is limited by federal regulations, there is a lot of promise in what is happening within these two industries today.

Even though these technologies have clear benefits, they are still not yet employed within the largest commercial aircraft category, which is airline travel. Airlines today still employ the use of a two-pilot crew within nearly all their fleet. The technology within these airplanes has advanced drastically throughout their time in service, but autonomy is not something that has made its way into the cockpit just yet. However, many large aircraft nearly have the capability of autonomy. Some of the largest jets in service not only have the capability of flying themselves at cruise, but also are equipped with automatic landing and braking systems, which allow for landings with almost no visibility on the ground. In the past year, Garmin has also introduced a similar system within the realm of general aviation, with their Autoland system being placed into Piper and Cirrus aircraft (Goyer, 2020). With the ready use of these technologies in the cockpit, it may seem that autonomy may be right around the corner within in aviation, but it may not be so straightforward. There are still two pilots within the cockpit of large commercial aircraft, who are constantly monitoring the systems, to maintain safety. Failures are far from rare in flying, and there are countless incidences where a very capable pilot needed to use their skills to save the flight from disaster. Also, since aviation is a much higher risk field, change is very slowly adopted. The aviation industry prides itself on its safety record. This incredible record of safety is in large part due to the cautiousness of the individuals involved. While a systems failure in a drone used to deliver packages could result in injury or even the death of bystanders, the damage would be limited to a small area. However, a computer failure in an autonomous Boeing aircraft could cost hundreds of lives, and possibly even more on the ground. Knowing this, an already over cautious group of aviators is going to be much less receptive to technological changes within the field, and although the technology may be there for safe autonomous flight, this could be a large hurdle for the integration of the systems into the everyday operations of the airlines. However, this is only the first hurdle that lies in the way of progress within this realm of aviation. Other hurdles include technological challenges, legal restrictions, cost, economic fallout, and public perception. Each of these issues will be discussed throughout this study, to give an overview of what lies in the way of the adaptation of UAS technology into the airlines and what the future of commercial aviation may look like.

Background

Technological Factors

Perhaps the most basic hurdle that must be overcome before any type of technology can be developed is the technical specifications that allow the technology to perform as intended. UAS have shown promise in many areas, but autonomy is still a developing technology. To perform as needed, drone technology must be capable of maintaining safe flight during all operations, but it also must be able to adapt to situations that arise in flight. To give an illustration from everyday life, cars are becoming increasingly autonomous on the road, with some manufacturers even claiming full autonomy. However, as some of the recent Tesla accidents have shown, the technology is far from ready for public reliance (Bigelow, 2021). The same issues that have plagued these vehicles could also apply to UAS technology.

Sense and Avoid Technology (SAA)

Perhaps the main technological challenge that has led to these aforementioned Tesla accidents and that must be overcome is to teach these machines to see and avoid. Cameras and sensors allow autonomous drones to see what is in front of them, but machines must be able to interpret the picture to make an accurate decision on what must be done to maintain safety. See and avoid technology has been a field of development over the past several years, but if the technology is so far from perfected in vehicles, it likely cannot be trusted in aircraft either. Gardi et. al. (2017) states that "The maturity of SAA techniques and enabling technologies is considered very limited when viewed in the perspective of civil airworthiness regulations for manned aircraft, raising concerns to certification authorities and airspace users" (p. 736). While this technology is still developing, it is still a long way away from being ready for large-scale public use, and it must be perfected further to allow for safe passenger flight in autonomous vehicles. Commercial aviation standards can be very stringent when it comes to passenger safety and can also be much slower to adapt to technological progress. As the authors noted above imply, there has been much progress within the field of UAS sense and avoid technology, but it is a long way away from meeting the safety standards already set forth in the commercial aviation industry today. Knowing these technological challenges faced by the UAS industry, researchers and aviation engineers are facing these challenges today, to provide more advanced drone products to the public tomorrow. These advancements can be seen in a few areas. First, progress within the area of sense and avoid is continually being made by researchers around the globe. Services like TCAS and ADS-B have been around decades and have done a good job of supplementing humans in safe air traffic operations. TCAS is even capable of taking control of the aircraft as needed to avoid a mid-air collision. Similar technologies can be equipped on drones, but there are a few problems with simply employing technologies like this to fulfill the sense and avoid requirements that must be satisfied before autonomous technology can be presented to the public. These supplemental services are intended to aid a human pilots and ground controllers, who are responsible for the safe operation of the flight. It is ultimately the responsibility of the pilot in command to maintain vigilance and respond to any dynamic threats that may be observed from the cockpit. To match the performance of these pilots, the electronic systems of UAS must be able to act similarly. This requirement means that machines must first be able to interpret the environment surrounding the vehicle, then process the information that is gathered, and finally react accordingly. Various technological advancements have been made in the last few years to allow unmanned aircraft to do just this. The first step in allowing the aircraft to “sense and avoid” is to equip the machine with a visual sensor of some form. These sensors range from cameras that allow the aircraft to see a lot like humans would see the environment, to radar, to LIDAR, to lasers, and to all sorts of different sensing methods. Each of these methods has benefits and drawbacks of their own. And so, it is also important to consider how different factors, such as rain and snow, will impact each of the sensors. Environments like these that include precipitation tend to favor sensors like radar, which would not be largely impacted by environmental changes quite as easily as a camera (Accardo et. al., 2012). However, new advancements are coming out often as the technology develops into a staple within many different commercial fields. Selecting the appropriate sensor for each unmanned aircraft can be difficult and must be backed by research. As discussed earlier, different sensors have different benefits and drawbacks involved, so making an educated call on the correct sensor is imperative

Table 1- *(Balestrieri et.al., 2021)*

Functions	Sensors	Specifications
Sensing and avoiding capabilities	Radar	Detection range 35 km
	LiDAR	Detection range 15 km
	Electro-optic sensor	Detection range 20 km

LiDAR	Radar	Utrasonic	Monocular Camera	Stereo Camera	Omni Direction Camera	Infrared Camera	Event Camera
High accuracy	Medium accuracy	Low accuracy	High accuracy	High accuracy	High accuracy	Low accuracy	Low accuracy
Range <200 m	Range <250 m	Range <5 m	Range operational environment dependent	Range <100 m	Range operational environment dependent	Range operational environment dependent	Range operational environment dependent
Affected by weather	—	—	Affected by weather and illumination	Affected by weather and illumination	Affected by weather and illumination	Affected by weather	Affected by weather and illumination
Large size	Small Size	Small size	Small size	Medium size	Small Size	Small size	Small size
High cost	Medium cost	Low cost	Low cost	Low Cost	Low Cost	Low cost	Low cost

to safe operation. Table 1 is taken from Balestrieri et.al. and it discusses the advantages and drawbacks of using each of the various sensor types (2021). As the table displays, it can be hard to decide which sensor would be best for each application as each is good and bad in its own way. One possible way to counteract this problem in large, commercial UAVs would be to equip the aircraft with a myriad of sensors, and to also equip the computer with an algorithm or artificial intelligence program, which could take various different environmental considerations into account when deciding how to combine the information that is perceived or when deciding which sensor should be actively monitored during the phase of flight.

System Redundancy

Accardo et. al. (2012) states that “sensor redundancy permits to increase overall system reliability and robustness in order to attain required levels of performance in terms of false alarms and missed detections” (para. 4). This statement supports the above assertion that a possible method of placing various sensors on commercial drones could help to bolster weaker sensors with sensors that are stronger in those areas. However, before this can be an effective tool for drones, the computers that fly them must be taught how to interpret the sensors that are equipped. One possible method for solving this issue is to have a primary sensor, and then supporting sensors, which help to ensure accurate readings from the primary sensor. This primary and supporting sensor method has the capability of working well, due to the different sensors supporting each other, but discretion must be maintained when deciding the roles for each sensor. Systems should also be equipped to monitor themselves for accuracy in the case of a component failure. Anyone who has worked with technology can say that it is far from perfect, and human intervention is often necessary to correct errors that are made by technological systems. Within the realm of aviation, these failures can often occur with automated systems. There is a saying in aviation that the autopilot will try to kill a pilot who is not paying attention, and although facetious, there is some truth to this saying. A quick look at the Boeing 737 Max accidents that occurred over the past few years display what faulty automation and sensors can do, and while there were capable pilots onboard, the automation still costs hundreds of lives. Instances such as these make it easy to see that computer systems must be closely guarded for accuracy within flight. Electronic components experience failures regularly, and it is the job of pilots to be able to detect and mitigate these hazards. An advanced drone must be able to do the same thing to replace the jobs of humans. There must also be redundancy of systems to be able to take over for a failed component. An electronics failure would also be much more hazardous in an autonomous vehicle. So, there must be redundant sources of power for the computer and sensors. One possible way to mitigate the redundancy issue is to keep a single pilot in the cockpit, to monitor the computer. The pilot would be able to determine failures and take over aircraft control in the case of system error. Having a single pilot cockpit is just one possible solution, but this is just another area that needs to be solidified before autonomous aircraft begin to carry passengers commercially. Overall, with regards to technological specifications of UAS technology, most of the advanced technology required to maintain safe flight may already be in existence, but there is a level of refinement, research, and a reliable record demonstrating safety that must be documented before large-scale passenger drones can even be considered by aviation regulators, executives, or the public. However, as technology rapidly moves forward, there will likely be a day in which these drones will reach the technological level necessary to replace the pilot, and that date is more a matter of when that will happen, rather than if that will happen.

Cybersecurity

Another major security threat that faces all computer-based fields is the threat of cyber-attacks, but these threats become even more serious when they occur to computers transporting passengers. Pyzynski & Balcerzak (2021) state that "The civil aviation industry and UAS industry need to be aware of the importance of cybersecurity within the UAS operations as well as emerging cyber threats associated with the increasing technology development, digitalization, and connectivity" (p. 10). As this statement implies, there are various threats to the computer systems that exist in aviation with regards to autonomous systems. A few years ago, Iran managed to capture a United States military drone, relatively undamaged. Iran claims to have captured this drone by jamming the communication signals and spoofing the GPS, but it is unknown how accurate this information is (Bhatti et. al., 2012). However, there have been demonstrations that methods like these could be effective for terrorists to take down aircraft. It is imperative that issues like these be addressed and fully fixed before drones are allowed to operate fully autonomously with passengers on board. GPS signals are also not the only systems that could be hacked by malicious entities. Navigation and communication hacks could also happen with piloted aircraft, but a human pilot should be able to detect maladies within the aircraft systems and figure out a possible alternative course of action for the safe continuance of flight. However, as computer technology continues to advance, and automation plays more of a major role in civil and government affairs, cybersecurity research continues to advance as well. There must be a consistent record of safety demonstrated before passengers are allowed on board. Much of this likely must be demonstrated by testing, but these areas of safety should be heavily considered by regulators before autonomous passenger airplanes are allowed to take to the skies. Although, modern research has led to possible mitigation of these problems, future research must always continue to stay ahead of the cybersecurity threats that face drones.

Economic Impact

Another challenge that presents itself with regards to the integration of unmanned aircraft into the existing passenger airline industry is the economic fallout that may occur, due to the displacement of jobs by robotic systems. The discussion of job automation is not new, and dates to the earliest history of mankind. New inventions make the lives of their users easier, but with that ease comes the capacity to eliminate the need for human labor. An example of this trend that is easy to see is observed when traveling on the interstate. Twenty years ago, tolls were paid to attendants who took cash and gave change back to drivers. Today, it is much more common to have high-speed cameras do this work instead of humans, and not much thought is given about it.

However, when the technology first came out, this was not the case. Thousands of jobs were displaced by these changes during the times of transition, impacting many lives. However, the empty status of toll booths today displays how technology still won out. Tolls are just one industry that has been heavily affected by automation, but there are many more. This trend of automation replacement has even been studied by academic researchers. However, the research that has come back on the topic has often been inconclusive, with some researchers stating that it hurts human jobs, others saying that it aids human jobs, and some saying that it does not affect human jobs (Dahlin, 2019). Much of this, however, must be determined on a case-by-case basis. It is estimated that the commercial and airline industries employed around 127,100 pilots in the U.S in the year 2019 (U.S. Bureau of Labor Statistics, 2021). While this is not a huge number, there are still a lot of jobs and families who depend on these flying jobs. The displacement of hundreds of thousands of jobs and the economic fallout thereafter could be another consideration for regulators to think about when deciding on the legality of these autonomous vehicles. Many career pilots have been trained and worked for a large portion of their lives to equip themselves to fly airplanes commercially, and not only would a total switch to autonomous aircraft dry up the job opportunities available to these pilots, but it may leave many individuals without a specialized field to work in. One author states that people are often resistant to change, which will already slow down the integration of new technology into the existing aerospace system of today, but those who are impacted in their everyday lives are likely to put up an even bigger fight to these changes, which will likely delay the integration even further (National Research Council et al., 2014). The same book even points out the single pilot transition as a possibility for progress. However, it must be considered that most pilots are protected by a union, and while these transitions may be inevitable, pilot unions will most definitely put up a strong picketing and possibly legal fight. Technology will likely win out the day, but there could be serious delays in integration due to these factors. However, there are also some benefits to consider when looking at adding autonomy. Perhaps most notably, it could help to make air transportation more accessible to the public. Being a more stressful and riskier field necessitates higher wages be paid to pilots, ultimately increasing ticket prices for the passenger. However, with only a computer system to guide the plane, autonomous aircraft could be cheaper for the public, because nothing is paid to the entity piloting the plane. These savings could help to allow more individuals to travel by aircraft. The precision of computer-based systems could also help to increase the efficiency of air travel, by cutting down on mistakes and accidents, and by allowing for more precise routes to be flown. With most technological advancements, the risks must be weighed against the reward, to see if proceeding with the technology is worth the investment and the disruption. It is likely just a matter of time before the necessity for pilots begins to wane, but for the time being, regulators must ponder how this change could impact lives, and how best to mitigate the negative effects on those whose jobs will be impacted by this technology. One possible answer to the problem of this transition could be the idea of a one person, one computer pilot crew during the first stages of technology integration. While jobs would certainly be lost and job opportunities would be greatly lessened, there would still be jobs available, especially for more senior crew members. The slower and less drastic transition would help ease the economic hardship brought on by the changes, help to mitigate the negative public perception that is inevitable with these kinds of advancements, and mitigate the negative press that may be brought on by them. However, since current restrictions do not allow for a single individual to be in the cockpit by themselves, due to the safety risks brought on by an unstable crew member, a single pilot crew may not even be a possibility in the future. When deciding whether to automate, it is important to take all factors into account and weigh the cost versus reward. In the case of the toll booths discussed earlier, many jobs were lost, but paying tolls on the road became much quicker and easier for drivers. If the same is to happen in aviation, it should be demonstrated that the technology is either safer or much less expensive for passengers to fly. With motivations like these, it can be easier justified to switch to automated systems. It is also possible with the increase in electronic systems, that there will be an increase in computer-based jobs, to make up the difference. However, these risk versus reward situations must be individually weighed on a case-by-case basis, but like other fields have observed, technology will likely win at the end of the day. There are no quick or right ways to adapt these changes well, but there are certainly things to consider and methods for regulators to attempt when the day comes when technology is completely ready to replace the human pilot.

Legal Factors

A third area that concerns the adaptation of UAS technology into commercial airline transportation is in the realm of legal restrictions in place, which minimize the possible uses for drones in the national airspace system (NAS). In the past year, the COVID relief act of January 2021 opened the public to new possibilities for the use of drones in the United States. Modern legal acts have made progress towards writing a law code that is much more inclusive of unmanned aerial vehicles, but there are still some issues that keep UAS technology from being massively introduced into the commercial aviation industry of the United States. In the recent past there was really no way for drones to be certified to fly in airspace that was not set apart for unmanned use (National Research Council et. al., 2014). With these restrictions in the law code, special permission from the FAA was required in many different instances for UAS operators. Much of this is because the current code of federal regulations (CFRs) is not inclusive of UAVs, because much of it predates a lot of the UAS technology that has been researched and developed. Due to these factors, it can be challenging for UAS pilots and operators to freely operate their aircraft in the way that their manned counterparts are able to. These restrictions mean that there is a lot of work for the government and regulators to accomplish before UAVs can become a commercial staple within the country. However, the rules are beginning to change in favor of modern UAV systems, allowing for easier operation. There are myriads of rule changes ranging from remote ID to operation over civilians, but one area that could also make in impact is within the simple registration process.

Registration Restrictions

In the past, large drones (greater than 55 lbs.) had to receive an airworthiness certificate or special waiver to operate. However, in September of 2020, the rules were changed to allow for certification under "special class", if no passengers are carried. While this certainly does not allow for autonomous airline transport drones, it is a move in the right direction for the certification of autonomous drones for use in the commercial airline sector (Zoldi, 2021). Special waivers have also been granted to select drone operators to conduct their drones over top of by-standing civilians. A few companies have been able to obtain part 135 status for their operations, but these companies are rare, and it can be a difficult process to obtain the necessary requirements to be granted this status. One important development, however, is that as of March 16, 2021, small drones are now allowed to operate over people and moving cars, without obtaining special permission. The revocation of these restrictive rules has the capability to allow for numbers of new commercial applications for UAVs. Things like package delivery from companies such as UPS and Amazon could greatly benefit from these developments.

Integration into the NAS

Although there is a lot of progress being made in allowing easier use for UAS technology in the United States, there are still major hurdles for the large-scale integration of these UAVs into the already existing NAS, including how to manage manned and unmanned traffic within the same airspace. The combined airspace issue is perhaps the biggest regulatory hurdle facing UAVs today, but the FAA is seeking to solve these issues through the work of their researchers. Teams working on research in the BEYOND program and regulators within the FAA are working to sort out the issues facing UAS integration today and seek to pave the way for integration in the future. However, there must be improvements made to the current see and avoid technology that exists today, whether used for remotely operated drones or even for autonomous drones tasked with avoiding other aircraft by themselves. Much of the current rules about UAVs are based on the operator being able to see the drone, with the FAA being reluctant to allow for BVLOS (beyond visual line of sight) operations. However, progress is being made towards systems which can fly and maintain separation without pilot oversight. Regulators currently require that UAVs operating BVLOS must be equipped with DAA (Detect and Avoid) systems, that allow the drone to stay “well clear” of other traffic (Fang et al., 2018, p. 6). Systems such as ADS-B and radar can help to allow for this traffic separation and have shown promise in testing. Progress is being made towards the normalization of BVLOS operations within the NAS, with several operators being able to obtain waivers from the FAA and even the development of infrastructure for these operations. However, there are still a lot of drone operations being conducted in segregated airspace. In the United States, this means that much of the research is done using specified corridors for UAS flights to be conducted. These areas will likely expand as more research is done and as drones are more widely considered to be safe by regulators. However, some places are further along than the United States regarding integration of UAVs into the combined airspace system. One such place is Poland, which passed a law in 2019 which allows for some low-altitude BVLOS operations to be conducted away from segregated airspace (Kasprzyk and Konert, 2020). Being able to achieve this is a major step towards drone integration. As of 2021, the United States has nearly obtained a similar level of integration, but waivers are still required today. While detect and avoid is the biggest hurdle that must be overcome with regards to BVLOS, another major challenge is to establish an Air Traffic Control like entity that can manage all of the drone traffic in the area and integrate it with the rest of the manned air traffic. Unmanned traffic management (UTM) systems are being developed by several agencies, as they seek to progress the research that is needed to safely integrate UAVs. Technologies like the newly required remote ID could help with this process, and advancements within the system keep coming out, making integration and autonomy much more of a reality than a dream (Zoldi, 2021). In the coming years, regulators will likely allow research to expand further and further, possibly even reaching large aircraft utilized by commercial cargo carriers, since these tests would propose a significantly lessened threat to human lives than their passenger carrying counterparts. These tests will likely be the basis upon which decisions are made about whether commercial flight is safe and possible without human pilots, and they may very well determine in large part when the time is right to allow for autonomy within passenger operations. In conclusion, integration may seem like it is a long way away when studying the current federal regulations, which were overwhelming written with manned aircraft at the forefront. However, as technology keeps changing, laws and the agencies that make them are adapting to the new technologies and consumer needs that face society. Organizations such as the FAA and European regulators are currently working on the best ways to safely use these technologies, allowing for a quicker integration time than may be expected. Current laws are still restrictive of UAS technology, but this is likely a very temporary issue that will change soon.

Airline Cost

Another issue that is sure to catch the eye of airline executives is the issue of aircraft cost. The lifespan of an aircraft is very different from the lifespan of a car. A twenty-year-old car would be considered pretty worn by most people, but pilots would likely think differently about aircraft. While aircraft certainly age and become obsolete eventually, the quality care that is put into each one of these machines helps them to last longer than their land bound counterparts.

Airplane Cost

One factor that no doubt plays a role in this longer lifespan is the cost of these airplanes. One Boeing 777-300ER is valued around 361 million dollars, which is a heavy investment for any company (Antonius et. al., 2018). Since these planes cost so much, airline executives and maintainers are motivated to get the most possible use for their money. This desire to get the most from their money translates to airlines operating airplanes that are often much older than some of the adult passengers on board. While this maintenance trend in aviation is great for cost savings, it will also certainly slow down the integration of autonomous aircraft into the airlines' fleets. While an airline may buy several new aircraft at a time, it is unlikely that they will replace their entire fleet at the same time, which would result in an unpayable bill that reaches well into the billions. It must also be noted that the aircraft that are coming out today are still intended to be manned by two pilots. With the hefty price tag of airliners and the general lifespan of these machines, it is unlikely that these two-pilot aircraft will disappear from airline service within the near future. Although, with companies like Airbus currently working on autonomy for their large passenger jets, the invention and possible certification of large, autonomous aircraft may be soon to come. However, the process of replacing airline fleets with these autonomous aircraft would likely be operation taking years to complete, which would allow for many pilots to keep their jobs, and curb the overall economic disruption caused by mass job displacement. While autonomy may come, it will likely come a little bit at a time, allowing for an easier transition between the manned system set up today and the possible autonomous systems of tomorrow.

Air Taxi Drones

Many of the autonomous aircraft that are currently planned for the near future are more of an air taxi type of operation, which would allow for short range autonomous flights across more urban areas. There are many difficulties with these operations, as have been discussed throughout this study, but these operations will likely be the first flights of the autonomous airline industry. Air taxi operations also became more legitimate within the airline industry within the past year, with United Airlines announcing a one-billion-dollar investment into the air taxi company Archer. These air taxis will not likely disrupt major air travel, as they are more intended to replace cars, but their success will likely pave the way for an expansion of the technology into longer-range passenger flights.

Maintenance Costs

Another factor to consider when observing the possible transition to unmanned aircraft is the maintenance costs of the autonomous systems themselves. While not having a human crew saves the airlines a lot of money, due to the lack of a salary, computers still need maintenance from time to time. Most airline pilots make a salary which is much higher than the average American worker, costing airlines into the billions of dollars each year (U.S. Bureau of Labor Statistics, 2021). Eliminating these positions could help airlines to save substantial amounts of money, but one factor that must be considered alongside of these savings is how much more autonomous airliners will cost to purchase, and how much more maintenance will cost for these aircraft. There will also likely be a bigger need for aviation mechanics who are proficient with computer and avionics systems that must be hired by the airlines. However, the increased cost associated with the aircraft themselves will likely not come close to the costs associated with paying pilots to staff long-range flights.

Effects of Cost Savings

Since less staffing is required to operate autonomous aircraft, it is possible that ticket prices could reflect the cost savings. In 2010, it was stated that labor was the second most expensive part of a commercial flight, with each crew member making thousands of dollars. Slashing operating costs in the area of payroll is a welcomed advancement in the eyes of many airline executives, and these saving could even come sooner than expected with major airplane manufacturers, like Embraer, surmising that only one pilot may be necessary soon (Bird et. al., 2019). However, this still does not change the fact that the overwhelming expense in aviation is the fuel. The eventual adaptation of electric airplanes could help to eliminate these extra expenses, but aviation will remain an expensive activity if fuel is involved. Airline travel will still be expensive, even on an autonomous aircraft, but there may be some discounted ticket prices due to the savings of not having to pay tens of thousands of pilots. On the other hand, the adoption of newer and possibly pricier airplanes into the fleet could increase ticket prices in the short term. Ultimately, technology will almost always lower the operating costs of the organizations who employ its use, but ticket prices could trend either way during the time of transition.

Final Thoughts

Overall, it will likely be a while before large-scale adoption of autonomous aircraft can really take hold within the aviation industry. The hefty monetary price tag associated with the adoption of an entirely new fleet alone is enough to delay the transition for years. However, much like the adoption of new aircraft today, it will most likely be a slow and methodical process of change for the airlines. In the end, airline operating costs will likely become markedly cheaper, allowing for a cheaper and more accessible airline industry in the future.

Public Perception

Perhaps the determining factor in the integration of autonomous aircraft into the commercial airline industry will be the public perception of the technology. In a free market society, the success of certain products or businesses relies on the way the public perceives the project, and if they are willing to spend money on the services provided by the company. The airline industry has demonstrated for many years that people are willing to spend a lot of money on air travel and that there is a lot of room for competition in the market, but this may not translate well to autonomous air travel, in large part due to the lack of trust that many people may have about autonomy.

Public Trust in Autonomous Aircraft

A 2018 study of individuals' perceptions about flying in autonomous aircraft is very telling of how the public would feel about flying in commercial aircraft without pilots. Although quite a few of the research participants felt neutral about the topic, about 70% of the individuals studied felt either very uncomfortable or uncomfortable with the notion of flying on an aircraft without human pilots. There was a group of people that felt comfortable with the notion, but those individuals made up a very small percentage of the group (Wollert, 2018). These results are very telling as to the process that will likely be necessary for the full adaptation of autonomous technology into everyday life. Another interesting find from the same study is that the highest number of participants in the study thought that autonomous passenger airlines would never become a reality, and while the individuals studied may not be experts on the topic, it is telling that there is a large percentage of the public that does not believe that airline autonomy will ever become a big thing (Wollert, 2018). However, a lot of determining factors may influence individuals' perceptions of the technology even today. Mehta et. al. (2019) states that "seven factors were significant predictors of WTF: familiarity with autonomous flight, fun factor, general wariness of new technology, age, education level, fear, and happiness" (para. 40). These variations within society means that while public perception and acceptance of autonomous flying technology may be poor overall, there may be certain subsets of the population or even other cultures that are more willing to accept the technology than others. These differences may result in the technology being introduced first in isolated areas, more willing to accept it, and its performance then being demonstrated to individuals who are less willing to accept the change.

Normalization and Integration into Other Fields

Another factor that is important to consider is that the overall mindset of the culture is likely to change as technology adapts and becomes more advanced. Individuals who grow up with technology are often more willing to use new technologies as they arrive and are likely more trusting of these technologies than people who have been introduced to them more recently. Society is also likely to shift as the safety and prevalence of new technology advances in the future. One such area that may help normalize the idea of autonomy in the lives of the public is the autonomous car. A 2017 study showed that the average consensus about self-driving cars is generally positive, with only 2% of the people studied feeling “very negative” about it, standing in sharp contrast with the general public’s opinion of self-operating aircraft (König & Neumayr, 2017). However, many other studies present conflicting data, stating that most individuals are not ready for self-driving technology yet. However, the public seems to be far more accepting of the idea of a self-driving car than an autonomous aircraft. While there are numerous different factors that may play a role in this perception, ranging from the greater control that the passenger has in their car, to the fact that a mishap in aviation poses a more severe threat to passenger safety, perhaps one factor that plays a major role is the familiarity of the idea. Self-driving cars have been an idea for a number of years, and they have also been on the market for quite some time. This time spent on the market and the general familiarity with the topic makes individuals likely feel more positive about the technology. This effect could also present itself with regards to autonomous flying technology. As drones become more common within the lives of the public, perception of the technology as a means of passenger air travel may trend to be more acceptable in the eyes of most consumers.

Challenges Facing Positive Public Perception

Even though these means of normalization could be effective to help the technology look more favorable in the eyes of the public, there are still some roadblocks to increasing public perception through such means. There have been several accidents involving autonomous vehicles throughout the years, calling into question the reliability of autonomous technology, and resulting in multiple deaths. Many of these instances have involved Tesla automobiles, demonstrating that self-driving cars may not be ready for mass public use, and while these instances certainly do not bolster consumer confidence with regards to autonomous technology, they likely do not have nearly the impact that the crash of an autonomous passenger aircraft would have on the society. No matter how well passenger drones may fare daily, just one accident while the technology is still in its infancy could be a death knell for these systems. Plane crashes already pique the interest of consumers all over the globe, calling into question the safety of facets of the aviation industry. These instances often provoke already conservative regulating agencies to bolster safety practices that may be associated with the accident. If an autonomous airliner were to crash soon, the response from an already hesitant regulator and consumer alike could be very adverse towards the autonomous technology. This hesitancy means that before the public is likely to accept the technology, there must be a very impressive safety record demonstrated by other fields using the technology and in the testing of the technology. This process of testing likely must be a very long process, that possibly must also include integration into other fields, such as long-haul cargo operations, before the technology is adapted to carry passengers. To help correct for these issues that are presented by the negative opinion of the public and the safety risks associated with autonomous flying, advocates for UAS technology must seek to make a strong case that autonomous flying is a very safe venture. While the integration of more advanced and autonomous technologies into daily life may make the average consumer more accepting of autonomous airline technology, there is still a lot of work to be done for proponents of UAVs. Swaying public perception must be a top priority for those in the UAS industry, or the greatest potential of autonomous aircraft may never be reached.

Results and Recommendations

Results

Although technological advancements have presented autonomous UAV technology as a serious possibility and have even made it a reality in the world today, there still may be many roadblocks to its full integration into all aspects of the commercial industry, specifically the passenger airline industry. Issues such as heavy regulation of the aviation industry and consumer confidence still indicate an uphill battle for the certification of the technology and its integration into everyday life. However, in the highly advanced and technological world of today, new advancements are continually being made, allowing for technologies that were not even dreamed of thirty years ago to be adopted into the everyday lives of citizens. While current advancements and the hopes of many individuals and organizations alike signal that autonomous travel may play a big role in the future, only time can tell of the advancements that will come or not come. However, the technological advancements of today indicate that autonomous air travel may not only be a very possible reality of tomorrow, but that it is likely even possible today. The issues that are presented in this report are in large part issues of refinement, not issues of impossibility, meaning that it is likely a matter of time and demonstration before these technologies are accepted, rather than an issue of whether these technologies will be accepted by society in the future. It is difficult to give a timetable on when autonomous air travel will be presented to the public, but the dynamic nature of tomorrow will likely determine the tardiness or abruptness with which the technology will be adopted. Autonomous airline travel is still an idea to be studied and explored today, but it may be an everyday staple for generations to come.

Recommendations

A lot of additional research can and should be done on each of the topics presented in this study. UAS technology is constantly changing and developing to address the needs presented by society, making it one of the more dynamic fields of study. As former research on the topic becomes obsolete, new research must be completed on the various topics relating to autonomous air travel integration. As technology is developed, it should be researched and studied to find new possibilities presented by new innovations, and as much of the future of autonomous air travel depends on the perception of regulators and the public, it is key that researchers allow these individuals to understand the reality of the technology available both today and tomorrow. Both finding the truth about the technology and informing others of that truth must be priorities for researchers in the future, and there should be a steady stream of research that is published about the topics relating to autonomous aircraft. There is still a lot of work facing researchers in this field, but the wealth of information coming out every day provides a substantial knowledge base to build a foundation for many years of future research.

Conclusion

The UAS field is one of the newest and most exciting fields in all of technological research, and as such, it includes a variety of unique opportunities for future use. As research becomes more complete on the topic, new applications are being developed and presented as either current or future possibilities. As perhaps the most important job in aviation, air travel is being targeted by many within the field as a major goal for the future. Though there are many hurdles for this to occur, the geography of the field is constantly shifting to allow for new innovations. There are no definitive answers as to what the integration of this new, autonomous technology will look like or if it will even happen. However, as much research indicates, autonomy could be the next revolution in the aviation field, and it may even be a reality in the very near future.

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