ADS-B AVIATION TECHNOLOGY

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Abstract*—Dated technology in aviation has left much room for improvement in both the safety and efficiency of flying. This paper will discuss the new Automatic Dependent Surveillance - Broadcast (ADS-B) technology and how it utilizes the global positioning system (GPS) technology to address the various challenges that stem from increasing plane travel and air traffic and to improve upon the general imprecision of radar. It is believed that the application of Automatic Dependent Surveillance - Broadcast technology in commercial airlines will optimize the efficiency of all current national and international flight systems. For pilots, it is paramount to have complete spatial awareness in the skies, otherwise congestion, delays, and even plane crashes can occur. This paper will discuss the goals of ADS-B technology and how it will affect the spatial awareness of pilots when flying. Currently, Automatic Dependent Surveillance - Broadcast has been implemented in some of North America and Europe and our paper will discuss how it is expected to spread further into Asia and the Pacific soon. We will analyze how ADS-B technology will lead to increased safety and number of flights, while decreasing costs and negative environmental impact through its creating of a network of full surveillance coverage. This paper will explore the perks of Automatic Dependent Surveillance - Broadcast that experts boast like how the technology allows for constant and precise location updates and other important information to both Air Traffic Control (ATC) and other aircraft. The paper will also go into detail on the hardware involved in Automatic Dependent Surveillance - Broadcast in and out, and the different options for pilots. Furthermore, we will thoroughly discuss the entirety of the global positioning system and how each piece comes together. This will help explain exactly how ADS-B works in terms of its use of the global positioning system.*

This paper will include how the application of Automatic Dependent Surveillance - Broadcast technology could have helped in the Malaysia Airlines Flight 370's disappearance and how it has impacted Malaysian Airlines current flights. ADS-B technology within planes allows for instantaneous satellite location tracking, opposed to traditional ground radar methods that were employed to track Malaysian Flight 370. Automatic Dependent Surveillance - Broadcast could have saved countless hours and millions of dollars searching for the lost flight. Catastrophes like that can hopefully now be avoided because the enhanced weather pattern intelligence ADS-B technology provides.

Keywords—ADS-B, Automatic Dependent Surveillance - Broadcast, Aeronautical Technology, Aircraft, Airplane, Air Traffic Control, ATC, Flight Technology, GPS, Navigation, Radar

INTRODUCTION: OPTIMIZATION OF THE FLIGHT INDUSTRY

Automatic Dependent Surveillance - Broadcast (ADS-B) is a revolutionary technology that has the potential to transform air traffic control (ATC). Automatic Dependent Surveillance - Broadcast is a relatively new information sharing and tracking system for airplanes that utilizes the very familiar Global Positioning System (GPS) that can be found in millions of devices around the world. ADS-B will soon be replacing the outdated radar technology that air traffic control has been using for many decades. The geographic precision and real-time speed are just two of the many ways that Automatic Dependent Surveillance - Broadcast technology eclipses the previous radar detection system. One benefit of ADS-B is the detailed account of all surrounding airborne bodies it can generate, which allows dramatically increased spatial awareness for pilots operating in the skies. With increased accuracy of information provided by Automatic Dependent Surveillance - Broadcast technology, air traffic control has a more precise broadcast of the upper troposphere and can generate more direct and optimized flight paths for all aircrafts. Shorter, optimized flight paths result in a decrease in flight time, fuel costs, and CO_2 pollution. ADS-B technology is arguably the solution to many of these long-term sustainability concerns within the aviation industry and projects to save owners, and the aviation industry, much money. Moreover, with all these advancements, flight safety is never jeopardized. Unfortunately, ADS-B could not have come soon enough.

The tragedy of the Malaysian Airline Flight 370's disappearance exploits the problems in radar-based flight tracking systems. Time, money, and most importantly lives could have been saved if Automatic Dependent Surveillance - Broadcast technology had been developed and implemented during the time of the incident. Following the incident, many different theories arose speculating that terrorism or a fire aboard the plane had caused the plane to seemingly disappear. However, all could agree that an incident such as this pointed to a need for better tracking of transoceanic aircraft across international borders. Their data transmission systems and transponders ceased to function and the need for ADS-B technology suddenly became very apparent. Automatic Dependent Surveillance - Broadcast has the potential to increase safety and save both money and time and hopefully with the worldwide implementation of ADS-B, Malaysian Airline Flight 370 will the last flight to disappear.

APPLICATIONS AND TECHNICAL SPECIFICATIONS OF ADS-B

By federal regulations 14 CFR 91.225 and 14 CFR 91.227, Automatic Dependent Surveillance - Broadcast technology will be used in some form or another in every aircraft that hopes to fly in controlled airspace in the U.S. by 2020. Automatic Dependent Surveillance - Broadcast comes in two varieties, there is ADS-B In and ADS-B Out. Only ADS-B Out will be required in 2020 by law, however both are helpful and recommended for pilots.

Overall, Automatic Dependent Surveillance - Broadcast technology utilizes the global positioning system to transmit and receive extremely accurate and up to date data from aircraft to satellite to air traffic control to other aircraft etc. The difference in ADS-B In and ADS-B Out is simple. Sarina Houston, commercial pilot, flight instructor, and expert in many things' aviation explains the difference best. An aircraft with "ADS-B Out has the capability of broadcasting its position, speed and altitude to air traffic controllers… [while] the ADS-B In capability will allow aircraft to receive traffic and weather information in real-time," overall allowing optimized routes for improved safety and efficiency [1].

Automatic Dependent Surveillance - Broadcast is far more accurate than radar, and this allows for more direct and efficient flight patterns. The uncertainty that was provided from radar forced air traffic control to create paths that were more spread out, but as a result, less direct. ADS-B decreases that uncertainty, which allows for air traffic control to direct planes closer together while keeping a safe distance between them. More direct flight paths mean that they are traveling the least distance possible, and thus use less time, fuel, and produce less emissions.

Hardware Specifications

Installing Automatic Dependent Surveillance - Broadcast can be as simple as plugging in an "ADS-B box", but that can depend on a lot of factors. There is a lot of specialized equipment that is a part of an Automatic Dependent Surveillance - Broadcast system. ADS-B Out requires a transmitter that fulfills the Technical Standard Order (TSO) [2]. The TSO is the government set of minimum capabilities of a certain technology [2]. As of December 2nd, 2009, the TSO for Automatic Dependent Surveillance - Broadcast is "Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Service - Broadcast (TIS-B) Equipment Operating on the Radio Frequency of 1090 Megahertz (MHz)" [3]. Also allowed as an ADS-B Out unit is what is known as a Universal Access Transceiver (UAT) which, unlike the TSO, also can access weather data from the Federal Aviation Administration's (FAA) ADS-B Out systems at a frequency of 978 MHz [4].

Radar VS ADS-B

When understanding the difference between radar and Automatic Dependent Surveillance - Broadcast, it is vital to know what a squit is. A squit is "a periodic burst or broadcast of aircraft-tracking data that is transmitted periodically" [6]. Squits are how aircraft send out information to air traffic control and other aircraft. The squits are sent out through radio waves. Before Automatic Dependent Surveillance - Broadcast technology, squits did not hold much information. Air traffic control would have received the squits and then would process the data to calculate all they needed to know about the plane's location and speed and would then send that information back out to other aircraft. Since the use of ADS-B technology, planes can now calculate all that information onboard and still be more accurate. Therefore, planes now need an extended squitter [6]. The planes have significantly increased the amount of information needed to be sent out in a single squit, so the squits need to be extended to carry all the information directly from the aircraft. The extended squit is far greater than the old squit that could send only about 7 "parameters"; the extended squit can do more than just double that figure, it can square it. The extended squitter can transmit 49 different types of data over the radio waves, including the intended flight path, giving the precise information of where the plane is, and where the plane is going to be [6]. The addition of this information easily justifies the relatively low cost compared to radar. "FreeFlight Systems will offer Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment priced below $2,000 for light general aviation aircraft that provides compliance with the FAA" [5]. This package would include antenna and installation kit as well. When looking at the cost of radar, "it can cost $10 million to $20 million to build a radar installation. With ADS-B, [ATC] get the same information at one-twentieth the cost" [5].

TSO VS UAT

Despite having the same overall function, the TSO and the UAT are not interchangeable. There are three major differences that one should consider when deciding on which to install. The first is altitude. In the U.S. it is mandated that at altitudes of 18,000 ft mean sea level (MSL, above the mean sea level) use the extended squitter, however, if below 18,000 ft MSL, then the UAT is acceptable. The second difference is location. The U.S. is the only country as of today that uses the UAT, meaning if a pilot is to cross any borders, the extended squitter is necessary. The third part is a little more complicated than the first two. The FAA still requires aircraft to have the old radar equipment ready to go as a backup for the Automatic Dependent Surveillance - Broadcast, which is fortunate for those who use the extended squitter because it has all the functions of the old machinery. Based on these three differences, it seems like the UAT is useless, but this is far from the truth. The UAT not only covers ADS-B Out, but also ADS-B In, and it has its own dedicated frequency of 978 MHz [6].

While ADS-B Out is the only required part, having ADS-B In is a huge benefit for any pilot. A pilot with ADS-B In can see exactly what air traffic control sees. The pilot can now see exactly where other planes are, and where they intend on flying. Using its own dedicated frequency is also a bonus. As more pilots broadcast over 1090MHz, there is the possibility for crowding up that frequency. By having its own frequency of 978 MHz, the UAT minimizes that effect [6].

INTERNATIONAL CREDENTIALS

There are many countries that are currently adopting Automatic Dependent Surveillance - Broadcast technology and this has influenced other countries to follow suit. Currently, "dozens of multilateration systems and over 1300 ADS-B ground stations have been implemented in more than 25 European States... related work is also being undertaken in all continents worldwide" including Africa, Asia, and South and Central America [7]. ADS-B Out has been mandated by the FAA to be incorporated in most airspace in which a Mode C transponder is required [8]. By January 1, 2020 aircraft will be required to have the Version 2 ADS-B Out system, which can be either a 1090 ES Automatic Dependent Surveillance - Broadcast system or a UAT Automatic Dependent Surveillance - Broadcast system.

All aircraft falling into Airspace A will be required to have the ADS-B equipment at any altitude. Those falling into Airspace B will be required to have Automatic Dependent Surveillance - Broadcast technology provided it flies between surface and 10,000 ft mean sea level. Airspace C aircraft from surface up to 4,000 ft mean sea level which includes the lateral boundary up to 10,000 ft mean sea level will be required under the mandate to install ADS-B technology. Aircraft under Airspace E, including those above 10,000 ft mean sea level over the 48 contiguous states including Washington D.C. and excluding airspace below 2,500 ft above ground level, will be required to use Automatic Dependent Surveillance - Broadcast [9].

In areas outside the United States, proposals to begin implementing the ADS-B technology have spread across the globe. In Australia, a requirement to have a 1090 ES for all instrument flight rules will be enacted June 6 of 2020. Canada currently holds no mandate, however, operators who voluntarily equip with 1090 ES can receive a higher level of service. Europe has made Automatic Dependent Surveillance - Broadcast mandatory for new-production aircraft and is calling for retrofitting on other aircraft by June 7, 2020. Although, Europe has pushed dates to meet the new regulations past when was previously expected, there are still preparations to implement the technology relatively soon. Hong Kong, Indonesia, Mexico, Singapore, Sri Lanka, Taiwan, and Vietnam all have some sort of 1090 ES requirement with slightly different altitude guidelines [8]. This widespread adoption of ADS-B is caused by new regional and global aviation initiatives, such as the Single European Sky and Next Gen, which promote increased aviation safety and sustainability. However, Europe has faced some setbacks and have pushed their set goal date back to 2020. Even with the later date, the European Commission has indicated it may have to allow some exemptions to the Automatic Dependent Surveillance - Broadcast equipage laws and the date may have to be delayed again. This set back has been accredited to need to install ADS-B In old aircraft.

While the safety benefits of Automatic Dependent Surveillance - Broadcast cannot be argued, the financial benefit can be debated when considering the cost to remove outdated technology and upgrade each aircraft. The cost to update older models has been estimated at $60,000 to $530,000 per aircraft [10]. A survey covering 35 different European airlines found that only 20% of aircraft are currently equipped with suitable ADS-B Out transponders. Increasing these percentages to the supposed goal is simply "not possible" because they did not "start with reliable plans" [10]. Future Asian and Pacific spread is due to global trends of surveillance modernization driven by Automatic Dependent Surveillance - Broadcast technology. Our clarification of how ADS-B has already been successfully implemented and improved flight systems in other areas of the world provides context for our investigation of the transformative nature of Automatic Dependent Surveillance - Broadcast.

TECHNOLOGY BEHIND ADS-B

The genius behind Automatic Dependent Surveillance - Broadcast is that it takes advantage of technology that was already around but uses it in a way never done before. Automatic Dependent Surveillance - Broadcast can achieve all it can do because it taps into the global positioning system. For example, “ADS-B capable aircraft uses an ordinary GNSS (GPS, etc.) receiver to derive its precise position… with any number of aircraft discretes such as speed, heading, altitude and flight number [and] then simultaneously broadcast to other ADS-B capable aircraft and to ADS-B ground” in real time [11]. It is very important to understand the global positioning system if one is to understand Automatic Dependent Surveillance - Broadcast.

The Constellation of Satellites

There are thousands of satellites orbiting the Earth [12]. The global positioning system uses at least 24 of the thousands of satellites [12]. These 24 satellites orbit the Earth twice a day in one of 6 designated orbital paths [12]. The 6 orbital paths ensure that the global positioning system is accessible from almost anywhere on Earth [12]. Due to an increase in satellites performed by the United States Air Force in 2011, 3 more satellites were added to create a 27-satellite system [12]. By this system, virtually anyone anywhere can have access to at least four satellites at any one time [12]. The satellites are tracked and monitored by various ground stations sprawled across the entire world [13].

Ground Control

The network of ground stations consists of one master control station and one alternative master control station both in the U.S. [13]. There are then 16 monitor stations that can be found on every continent except Antarctica [12]. The third part consists of the ground antennas of which there are four [12]. The process starts with the monitoring stations [12]. Six of the 16 stations are run by the Air Force, and the other ten are run by the National Geospatial-Intelligence Agency (NGA) [13]. The monitoring stations use GPS receivers to track the satellites and receive atmospheric data from them [13]. They then send this information to the master control station who uses this to evaluate the network of satellites among other operations [13]. The master stations have ultimate control over the satellite system for the global positioning system and do the most work and has many major functions [13]. First and foremost, the master control station tracks the precise location of all 27 satellites with the compiled information received from all monitoring stations [13]. At this point the people at the master control station can decide if it is necessary to give commands to the satellites in case, they need to adjust course [13]. If they decide this is necessary, they will send instructions to the satellites themselves [13]. Once the trajectory of the satellites is in order, the master control station will then monitor the satellite broadcasts and will continue to monitor the system in order to make sure that nothing is going wrong [13]. If something does go wrong, it is the master control station’s responsibility to fix the problem [13]. The final part of this portion of the global positioning system is made up of four ground antennas and seven Air Force Satellite Control Network (AFSCN) tracking stations that are both mostly found on different islands around the world [13]. These large antennas work as messengers when the master control station needs to send information or instruction to the satellites [13]. All of this is required to provide the global positioning system to millions of devices worldwide.

Figure 1 [9]
Mechanisms of ADS-B technology.

Visualizing the Whole System

In Figure 1, there is a visual of how Automatic Dependent Surveillance - Broadcast technology fits into the global positioning system. In the diagram, there is one satellite, but as previously mentioned, there would be about four satellites that would be involved at any one time. The satellite is sending data to the two different aircraft. The aircraft in the picture both are using ADS-B In and ADS-B Out and thus can communicate directly with each other. Individually they compile the information received from the satellites to calculate a multitude of parameters which they can then send to anyone fitted with ADS-B In. If this were a diagram of radar, not only would the planes be sending fewer quality data at a smaller quantity, the whole process would also be less direct. With radar, the planes would be receiving information from satellites then sending the information to ground control where the data can be analyzed, then relay that information to other planes. Automatic Dependent Surveillance - Broadcast technology acts as an intermediate step between different objects both in the air and on the ground. Transmitters and receivers all communicate every second making this technology unlike radar in its ability to have current information circulating between many different sites. Everything is constantly communicating with each other, making sure that everything involved is always up to speed. Our clarification of the basic processes of the global positioning system provides context for our investigation into the need to have improved flight tracking seen in the case of Malaysian flight 370, in the next section.

CASE OF MALAYSIAN FLIGHT 370

The case of Malaysian Flight 370 raises many issues within the efficiency of current technology in the aviation field. However, technologies developed in response to these tragedies, such as Automatic Dependent Surveillance - Broadcast tracking technology, are influenced by these issues to resolve similar tragedies in the future and to improve the quality of the aviation industry, according to scientists. Whereas "[it is] unclear whether satellite tracking would have changed anything in the aftermath of Flight 370's disappearance, [ADS-B's] real-time tracking would improve the aviation industry overall allowing planes to fly more optimal routes" according to chief executive Don Thomas [14]. In addition to more optimal routes, Automatic Dependent Surveillance - Broadcast aims to allow internal transmissions of location and performance data to be sent constantly, the geographic tracking of transoceanic and dead zone areas flights and frequent real-time tracking updates. Current aviation technologies, such as applications of ADS-B In and ADS-B Out, focus on minimizing foreseeable dangers and tragedies for pilots and aircrafts. Through much tragedy, the Malaysian Airline disappearance has made the need for improved aviation technology and safety apparent, and innovations such as Automatic Dependent Surveillance - Broadcast technology attempts to create a safer future for the aviation industry.

Flight 370's Disappearance

In March 2014, 239 passengers boarded Malaysia Airlines Flight 370 headed for Beijing, China—where Flight 370 ended up remains to "one of the greatest mysteries in modern aviation" according to scientists [14]. Whereas it is unclear if ADS-B technology could have impacted the disappearance and search for Flight 370, this disappearance demonstrates the limitations of radar and aviation technologies prior to Automatic Dependent Surveillance - Broadcast and accentuates the manifold of applications ADS-B technology provides to the field of aviation.

In a published report by Britannica, Malaysia Airlines Flight 370 took off at 12:41 am, eventually reaching cruising altitude at 1:01 am [16]. Within 20 minutes, Flight 370 sent its last Aircraft Communication Addressing and Reporting System (ACARS) transmission and turned off the plane's transponder; these systems internally reported information about the flight's performance and communicated with air-traffic control, respectively [16]. After Flight 370 crossed the South China Sea, at 1:30 am, Malaysian military and civilian radar began tracking this aircraft until the plane entered oceanic airspace again at 2:22 am and an Inmarsat satellite, a system comparable to early ADS-B technology, received geographic signals of this aircraft until 8:11 am [16]. For around seven hours Flight 370 was geographically located; half an hour by internal transmissions, one hour by radar, and five and a half hours by satellite only. Throughout this disappearance important issues arose surrounding aviation technology, such as the ability to easily disable internal transmissions of geographic and performance information, the geographic limitations of radar tracking and transoceanic tracking and the sparse use of satellite-based tracking, all of which solved by current ADS-B technologies. The "greatest mystery in modern aviation" may never be solved, but technology such as ADS-B has been greatly developed to avoid similar time, money, and life-costing tragedies [14].

Issues raised by the Flight 370's disappearance have influenced the development of Automatic Dependent Surveillance - Broadcast by irremovable internal transmission systems, developing reliable transoceanic tracking technology, and improving the frequency of satellite-based tracking. A controversial topic in the disappearance is the disabling of the ACARS and transponder systems within the plane because these systems are critical location and tracking communications. Although the disabling of these systems inhibits communication, ACARS and plane transponders are commonly turned off to prevent electrical shortages or fires and to not overwhelm air traffic controllers with excessive amounts of signals [16]. In current Automatic Dependent Surveillance - Broadcast systems, similar systems to ACARS and transponders are integrated into the hardware of Automatic Dependent Surveillance - Broadcast, preventing these systems to be disabled provided the hardware was installed, and ADS-B utilizes a 'moving map' allowing pilots to steer without the need of signals to air traffic control stations.

Another key issue was the limitations of radar technology when tracking over transoceanic routes and the infrequent data provided by Inmarsat satellite tracking. As stated in previous sections, the innovation of Automatic Dependent Surveillance - Broadcast was groundbreaking in the aviation field because of its ability for real time geographic tracking from any location. The spread of Automatic Dependent Surveillance - Broadcast technology continues to be adapted as “by 2020, the FAA will require planes to have ADS-B equipment to fly in most controlled airspace” in order to maximize these benefits [14].

The Search for Flight 370

In the search for Flight 370, researchers have used in flight evidence, such as communication logs and military and civilian radar data, in their search for the missing aircraft. While this evidence has been useful in providing leads for this search, the limitations of radar tracking and previous aviation communication technology became clear as the search led to no avail; triggering scientists to speculate whether this disappearance would have occurred if ADS-B was developed sooner [14]. This disappearance “triggered a multinational search for the wreckage through 46,000 square miles of the Indian Ocean that would wind up costing about $150 million” [14] and abandoned by the governments of Malaysia, China and Australia without conclusive results.

Flight 370 was a commercial plane traveling from Kuala Lumpur, Malaysia to Beijing, China, a journey that “would have taken it north-eastwards, over Cambodia and Vietnam [which led to] the initial search being focused on the South China Sea” [17] according to the plane’s scheduled flight path. However, military and civilian radar data “suggested the plane had suddenly changed from its northerly course to head west, then [switching the search] to the sea west of Malaysia” and further satellite analysis expanded the search, eventually confirming “the plane crashed in the Indian Ocean, south west of Australia” with several refined locations [17]. Prior to further satellite analysis, information withheld until eight days after the search began, the multinational search effort planned to scour nearly three million square miles of water (one and a half percent of Earth’s surface) [17]. The lack of consistency of tracking Flight 370 while in the air along with the withholding of flight information until weeks into the search, resulted in many mislead searches in large areas, including the South China Sea, Gulf of Thailand, Strait of Malacca and Southern Indian Ocean, and costing approximately $150 million and over four years for inconclusive results [14].

The missig Flight 370 had a profuse impact; not only were the loved ones of the victims affected, but also on the resource expenditure of multiple countries supporting the search. Specifically, Figure 2 details cost expenditure of the United States right before the underwater searching phase revealed inconclusive and the search was called off. Whereas the total multinational search effort cost reached over $150 million before the search ended [4], the United States contributed $11.4 million, split between on civic aid funds, operational costs and underwater search equipment, estimated as of April 24, 2014. Had more advanced tracking technology been available sooner, the $8.2 million for operations and underwater search equipment, along with over $100 million given by supporting multiple governments, may have been conserved for relief in countless other incidents.

Figure 2 [15]
US spending during 370 search

Despite all the delays that were caused by Malaysian authorities withholding information, much of the mislead searches are cause of outdated aviation practices and the limits to radar technology on transoceanic flights. The initial searched was focused on the South China Sea because air traffic control, prior to ADS-B technology, manually scheduled transoceanic flights by plane departure requests and monitored aircrafts speed to avoid oceanic collisions. By these outdated practices, air traffic control predicted Flight 370 to be along its designated route, located over the South China Sea, whereas further evidence provides Flight 370 veered off path immediately after entering airspace over the South China Sea. Furthermore, the evidence found during the approximate hour of military and civilian radar tracking, provided minimal clues to the whereabouts of this aircraft as radar and GPS tracking has clear limitations for transoceanic tracking. Unlike the restrictions on radar technology, Automatic Dependent Surveillance - Broadcast tracking technology provides resounding evidence when determining the location of transoceanic flights by utilizing frequent transmissions via satellites.

Aviation Technology Today

Following the disappearance of Flight 370, problems in the safety and efficiency of previous radar-based flight tracking systems were made clear. 239 passengers’ lives, four years, and $150 million dollars have been taken by this tragedy. If ADS-B technology had been implemented, we "would have known that it was MA 370, a Boeing 777 and the ADS-B unit on the plane would be giving someone its information within 30 meters every second" [18]. Although speculation will never determine how such a tragedy could have been prevented, new ADS-B technology has responded by providing systems to ensure a safer future in the aviation industry. Along with providing technology to support real time tracking over oceans and to supply constant locations of all aircrafts without obstructing airways, Automatic Dependent Surveillance - Broadcast technology also provides ADS-B In to further ensure airspace welfare. The combination of both ADS-B In and out technologies help pilots always increase their route efficiency and avoid dangerous weather patterns while tracking the aircraft's global position and avoiding larger aircraft catastrophes.

SUSTAINABILITY

Sustainability is one of the most important traits to focus on when designing anything. Questions about environmental and economic impact should not be left unanswered. The benefits of ADS-B cannot be understated; however, it gets tricky when trying to factor in cost. For some, this will not be a problem, but for many, this poses a real challenge. With the deadline rapidly approaching, aircraft owners who have not installed ADS-B Out should be looking to install it soon. As of November 2018, the FAA "estimates that between 100,000–160,000 general aviation aircraft may need to equip with ADS-B" [19]. At a few thousand dollars for ADS-B Out, and even more for the installation, this will be a multi-hundred-million-dollar upgrade for America. A steep price to start, but after everyone is equipped with ADS-B, there will not be another situation where the whole country needs an upgrade until the FAA decides to completely change the navigation system requirements again. After that headache is sorted out, the full effects of Automatic Dependent Surveillance - Broadcast can finally be felt. Already there has been an impact. Research by the FAA in 2015 found that for transoceanic flights, "ITP-equipped [ADS-B In equipped] aircraft saved an average of 86 gallons of fuel per flight compared to non-equipped aircraft" [19]. For a car, 86 gallons is excessive, but to a plane, it is hardly anything. However, with thousands of flights a day, 86 gallons saved per flight can quickly jump to thousands of gallons saved. With statistics such as this one, considering long term impacts of the sustainability of ADS-B technology is critical. For example, the FAA has also found that "Flights that use a special ADS-B route in the gulf due to thunderstorms or headwinds on legacy routes save an average of 7–11 minutes of flight time and burn less fuel, which saves money and cuts aircraft exhaust emissions compared to flights using traditional routes over land" [19]. This decrease in flight time will allow for less delays during times where there is a high volume of air traffic [19]. The FAA also estimates that by 2035, $70 million will be saved by the already increased ADS-B ground control stations in the Gulf due to the increase in air capacity from more efficient flight paths [19]. Before ADS-B, flights over water had to be 30-80 nautical miles (1 nautical mile = 1.151 miles or 1.852 km), but with ADS-B, flights can be as close as 15 nautical miles, a stark difference [19]. Overall, this will lead to an increase in flights, while reducing individual fuel use and decreasing flight time. The payout is currently very large, but ADS-B proves itself to be environmentally and economically sensible in the long run.

CONCLUSION: TRANSFORMATION OF THE FLIGHT INDUSTRY

By taking advantage of the global positioning system, ADS-B has the potential to optimize flight patterns around the world. Analysis of ADS-B through the lens of efficiency and safety make it the more attractive choice. On top of this, its accurate and precise tracking method make it the better choice compared to dated radar technology. When comparing the technology to the global positioning system, the simplicity of the relationship between the transmitters, receivers, and satellites allows for a good understanding of the communication process in Automatic Dependent Surveillance - Broadcast. Upon further analysis, the more complicated relationship between storage of data and processing of data is revealed using squits to hold parameters of information. The need for extended squits in ADS-B technology exhibits the extreme increase in fulness of data from radar to ADS-B. Air traffic control will be able to create more direct flight paths using that information that decrease flight time, fuel costs, and emissions. Automatic Dependent Surveillance - Broadcast is clearly a more sustainable choice, although, the cost has proved to be troublesome when it comes to updating old technology. Manufacturing new aircraft with the technology is easily done, however, the goal of countries looking to update their aviation technology struggle to see where the funding to update entire fleets will come from. Though currently mostly in North America and Europe, Automatic Dependent Surveillance - Broadcast will soon find itself traveling across the globe. Many countries have set lofty goals, some facing setbacks, that generally intend to install ADS-B Out in their aircraft. There are usually some exceptions, based on domestic status and altitude levels. These new regulations intend to increase the safety of flight travel and transport. The need for new technology in aviation is not without provoke. Catastrophes like the Malaysian Airline Flight 370 will be diminished domestically as the U.S. has mandated that all planes that wish to fly must be fitted with ADS-B technology by 2020. The Malaysian Airline Flight 370 disappearance advanced the discussion on ADS-B, as the disappearance exploited the need for better tracking tools. Since the accuracy and precision of tracking is one of the main ways Automatic Dependent Surveillance - Broadcast surpasses radar, the implementation of ADS-B after the Malaysian Flight 370 increased. Despite fear being one of the initial fire-starters to this technology, Automatic Dependent Surveillance - Broadcast leaves no room for fear. Between the increased accuracy of location and the wide range of data able to be stored under ADS-B, an emergency can easily be handled as data from one flight is updated to all others that offer help or be affected. This proactive method of dealing with conflict should ensure all that Automatic Dependent Surveillance - Broadcast is a secure method of tracking.

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