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Report to the Committee on Transportation and Infrastructure, House of Representatives

July 2019

AIR TRAFFIC CONTROL

FAA's Analysis of Costs and Benefits Drove Its Plans to Improve Surveillance in U.S. Oceanic Airspace

Accessible Version

GAO-19-532

GAO Highlights

Highlights of GAO-19-532, a report to the Committee on Transportation and Infrastructure, House of Representatives

July 2019

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Why GAO Did This Study

Recent developments in surveillance technologies, which provide an aircraft's location to air traffic controllers, have the potential to improve air traffic operations over the oceans. FAA has explored how to improve surveillance capabilities in U.S. oceanic airspace to take advantage of new international separation standards that could lead to the more efficient use of this airspace.

GAO was asked to review planned improvements to aircraft surveillance. This report examines: (1) FAA's approach to enhancing surveillance capabilities to improve safety and efficiency in U.S. oceanic airspace and (2) selected aviation stakeholders' perspectives on FAA's approach.

GAO reviewed documents related to FAA's planned investment in enhanced oceanic surveillance and interviewed FAA officials working on this effort. Interviews included those with the Air Traffic Organization and air traffic controllers who manage U.S. oceanic airspace. GAO surveyed representatives of 14 commercial airlines, including 11 U.S. and foreign passenger airlines, which were selected based on factors such as flight volume; and 3 U.S. cargo airlines, which were selected based on tons of cargo shipped. GAO also interviewed other aviation stakeholders, including trade associations, unions representing pilots, and foreign air navigation service providers that manage airspace adjacent to U.S. oceanic airspace.

View GAO-19-532. For more information, contact Heather Krause at (202) 512-2834 or krauseh@gao.gov.

What GAO Found

The Federal Aviation Administration (FAA) evaluated two aircraft surveillance technologies that would allow aircraft to safely fly in closer proximity while in oceanic airspace. Based on its evaluation, FAA committed to using one in the near term and to continue to study another for future use. Specifically, in April 2019, FAA committed to implement by 2022 new international standards that allow reduced distances between aircraft, called minimum separation standards. These reduced distances would be enabled by a surveillance technology known as enhanced Automatic Dependent Surveillance-Contract (ADS-C). FAA also decided to continue studying the use of another enhanced surveillance technology known as space-based Automatic Dependent Surveillance-Broadcast (ADS-B)—to further improve surveillance in U.S. airspace. Both technologies offer increased frequency in reporting of an aircraft's location, which enhances safety, and can support new minimum separation standards. FAA decided to proceed with enhanced ADS-C in the near term because the efficiency benefits to airspace users exceeded the costs of more frequent location reporting and air traffic control system upgrades by 2 to 1. In contrast, FAA determined that the costs of using space-based ADS-B in U.S. oceanic airspace outweigh the efficiency benefits by 6 to 1. FAA officials added that operational challenges to using space-based ADS-B to manage air traffic in U.S. oceanic airspace have not yet been resolved. FAA plans to continue studying potential uses for space-based ADS-B in U.S. airspace to determine if benefits can outweigh the costs (see figure).

FAA's Near-Term, Medium-Term, and Long-Term Plans to Study Options to Enhance Surveillance

Plan	Term
Conduct operational evaluation of space-based Automatic Dependent Surveillance-Broadcast (ADS-B) in U.S. offshore airspace	Near Term (1-3 years)
Study using space-based ADS-B when ground-based surveillance infrastructure is unavailable	Medium Term (3-5 years)
Study operational challenges in U.S. oceanic airspace and potential solutions	Medium Term (3-5 years)
Study using space-based ADS-B in U.S. oceanic airspace	Long Term (5+ years)

Source: GAO analysis of FAA documents. | GAO-19-532

GAO found that most selected airlines (11 of 14) support FAA's overall approach to enhance oceanic surveillance. Selected airlines also said they expect the new minimum separation standards to improve access to more direct and fuel-efficient routes. FAA is taking steps to provide these benefits by restructuring routes in one area of U.S. oceanic airspace and by applying new minimum standards to give aircraft better access to fuel-efficient altitudes. According to FAA officials, however, additional benefits, such as redesigning other U.S. oceanic airspace, expected by selected airlines are limited by (1) relatively low rates of aircraft equipage with the technology that enables reduced separation and (2) the frequency of disruptive weather patterns in parts of U.S. oceanic airspace.

Contents

Abbreviations

ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance-Contract
ASEPS	Advanced Surveillance Enhanced Procedural Separation
ATOP	Advanced Technologies and Oceanic Procedures
ATS	air traffic service
CPDLC	Controller Pilot Data Link Communication
ERAM	En Route Automation Modernization
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FIR	flight information region
ICAO	International Civil Aviation Organization

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

July 17, 2019

The Honorable Peter DeFazio
Chairman
The Honorable Sam Graves
Ranking Member
Committee on Transportation and Infrastructure
House of Representatives

Over the past decade, the Federal Aviation Administration (FAA) has provided air traffic control services to over 18 million flights traversing the airspace above the Atlantic, Pacific, and Arctic oceans. With international air traffic expected to grow, FAA must modernize to continue meeting its goal of providing the safest, most efficient airspace system in the world.[1] Recent developments in surveillance technologies, which provide an aircraft's location and other information to air traffic controllers, have the potential to help FAA manage oceanic air traffic more efficiently while maintaining a high level of safety. For example, Aireon—in partnership with air navigation service providers from around the world and Iridium Communications—is using a constellation of recently deployed satellites to provide near real-time surveillance of suitably equipped aircraft anywhere in the world.[2]

You asked us to review planned improvements to aircraft surveillance in oceanic airspace. This report addresses:

- FAA's approach to enhancing surveillance capabilities to improve safety and efficiency in U.S. oceanic airspace and
- selected aviation stakeholders' perspectives on FAA's approach to enhancing surveillance.

To address both of our objectives, we reviewed FAA's and other aviation stakeholders' documents on the management and organization of U.S. oceanic airspace; the functionality and use of communication, navigation,

[1]FAA, *The Future of the National Airspace System (NAS).* (Washington, D.C.: June 2016).

[2]Aireon provides global surveillance services to air navigation providers and airlines. Iridium Communications is a satellite communications provider that offers global voice and data communications.

and surveillance equipment in aircraft flying in U.S. oceanic airspace; and descriptions of the enhanced surveillance technologies that were being considered by FAA—space-based Automatic Dependent Surveillance-Broadcast (ADS-B) and enhanced Automatic Dependent Surveillance-Contract (ADS-C). To understand how space-based ADS-B and enhanced ADS-C would function, we interviewed representatives from Aireon, which offers the space-based ADS-B service, and Inmarsat, which provides the primary satellite communication network used by the providers of ADS-C services. We also interviewed other aviation industry stakeholders, including trade associations representing aircraft operators and unions representing pilots.

To examine FAA's approach to enhancing surveillance capabilities in U.S. oceanic airspace, we reviewed FAA documents and interviewed FAA officials. Specifically, we reviewed documents prepared by the Advanced Surveillance Enhanced Procedural Separation (ASEPS) program for FAA's planned investment decision. These documents included the business case analysis and safety risk management assessments of enhanced surveillance technologies. In reviewing the business case analysis, we did not independently evaluate the methodology or data sources used. We interviewed FAA officials and program managers who are working on different elements of FAA's efforts to enhance surveillance in U.S. oceanic airspace, including relevant offices within the Air Traffic Organization;[3] other offices within FAA, such as the Flight Standards Service; and the contractors who prepared FAA's business case analyses.[4] We interviewed FAA air traffic controllers and their union representatives at the Anchorage, New York, and Oakland air route traffic control centers, which are responsible for managing air traffic flying through U.S. oceanic airspace. We also interviewed or received written responses from representatives of the air navigation service providers in Canada, Japan, Portugal, and the United Kingdom—which are

[3]The Air Traffic Organization is the operational arm of the FAA. It is responsible for providing air navigation services to all U.S. airspace.

[4]Several offices within FAA are involved with the effort to enhance surveillance in U.S. oceanic airspace. These include the ASEPS program, which managed the evaluation of surveillance technologies; the Oceanic/Offshore Standards and Procedures Branch, which oversees air traffic operations in oceanic airspace such as facilitating changes to air traffic procedures and systems to enable the use of new technologies and new standards; the Flight Standards Service, which works to improve flight operations, standardization, and aviation safety across U.S. and international airspace systems; and the Advanced Technologies and Oceanic Procedures (ATOP) Program Office, which oversees changes to the air traffic control computer system used to manage oceanic air traffic.

responsible for oceanic airspace adjacent or close to U.S. oceanic airspace—to understand their plans to enhance surveillance capabilities.

To obtain selected aviation stakeholders' perspectives on FAA's approach to enhancing surveillance in U.S. oceanic airspace, we selected 14 U.S. and foreign commercial airlines, including passenger and cargo airlines. Using FAA data from fiscal year 2016, we selected 10 passenger airlines with the highest flight volumes in U.S. oceanic flight information regions. We selected an additional passenger airline because it planned to begin service in U.S. oceanic airspace. We also selected three large U.S. cargo airlines, based on tons of cargo transported, to ensure that the cargo airlines' perspective was represented. We conducted a follow-up survey of these 14 airlines to obtain their responses on safety in oceanic airspace, benefits of reduced aircraft separation standards, and FAA's planned approach to enhancing surveillance capabilities. In this report, we use the following conventions in reference to information obtained from the 14 selected airlines: "several" is three to seven, "many" is eight to 10, and "most" is 11 to 13. Further details about our scope and methodology are in appendix I.

We conducted this performance audit from March 2018 to July 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

U.S. Oceanic Airspace

FAA, within the U.S. Department of Transportation, provides air traffic services for the continental United States (domestic airspace)[5] and over parts of the Atlantic, Pacific, and Arctic oceans (oceanic airspace). More

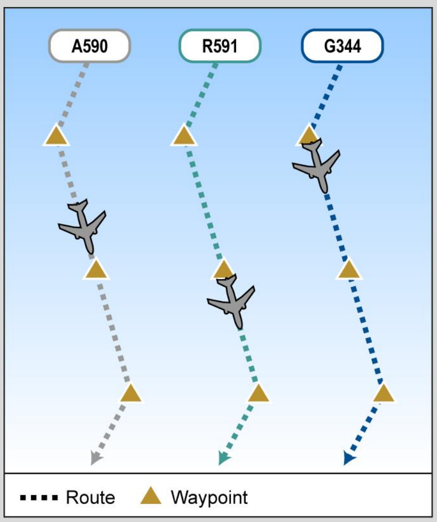
[5]U.S. domestic airspace is the airspace that overlies the continental land mass of the United States plus Hawaii and U.S. possessions. Domestic airspace extends to 12 miles offshore.

Aircraft Routes and Track Systems

Route is the path an aircraft takes as it flies over the Earth's surface.

Air traffic service (ATS) route is a specified route designed to channel the flow of traffic as necessary for the provision of air traffic services. ATS routes are defined by predetermined geographical positions—waypoints. For example, ATS route G344 is published by FAA and is defined by waypoints.

Organized Track System is a series of ATS routes. For example, A590, R591, and G344, along with other ATS routes, comprise the North Pacific Route System.



Source: FAA and International Civil Aviation Organization. | GAO-19-532

than 24 million square miles of oceanic airspace are under U.S. control.[6] This airspace is divided into flight information regions (flight regions): Anchorage Arctic, Anchorage Oceanic, New York Oceanic, and Oakland Oceanic.[7]

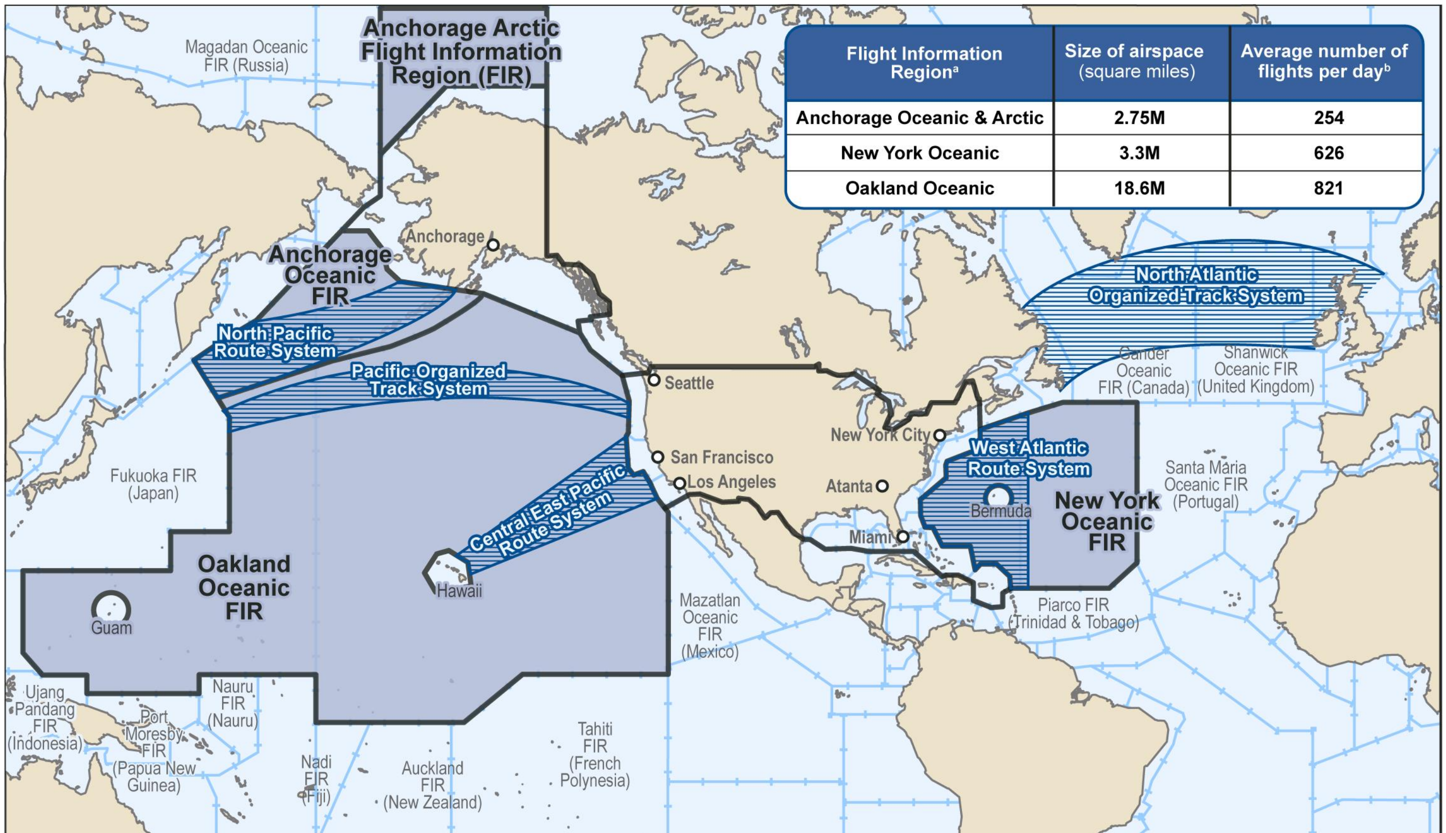
In areas with high flight volume, such as between California and Hawaii, FAA publishes air traffic service (ATS) routes that allow air traffic controllers to handle large volumes of traffic. A set of ATS routes—an organized track system—functions as a freeway in the sky, with routes serving as lanes (see sidebar). ATS routes may be "fixed" or "flexible." A fixed route does not change; whereas a flexible route changes daily depending on weather patterns, such as prevailing winds. As detailed in industry reports, multiple factors—including weather conditions, congestion, and airspace restrictions—affect whether aircraft operators plan to fly on ATS routes published by FAA or on routes they determine to be the most efficient for that flight (i.e., user-preferred routes).[8] Figure 1 shows U.S. oceanic airspace and the location of various organized track systems.

[6]The International Civil Aviation Organization (ICAO), a United Nations specialized agency, promulgates international standards and recommended practices aimed at standardizing international civil aviation operational practices and services. The United States is a member of ICAO and has agreed to follow its obligations under the Convention on International Civil Aviation. Specifically, the United States accepted responsibility for providing air traffic control services in U.S. domestic airspace. The United States also manages airspace outside of U.S. domestic airspace—U.S-controlled oceanic airspace, to which the United States applies procedures consistent with ICAO procedures. All mentions of "U.S. oceanic airspace" in this report refer to U.S-controlled oceanic airspace.

[7]In addition to the Anchorage Arctic, Anchorage Oceanic, New York Oceanic, and Oakland Oceanic flight information regions, there are three other oceanic flight information regions managed by FAA—Houston Oceanic, Miami Oceanic, and San Juan Oceanic. FAA classifies these as "offshore" airspace, which means they cover airspace between the 12 nautical mile limit of domestic airspace and the boundary of oceanic airspace. Throughout this report when referring to U.S. oceanic airspace, we mean the Anchorage Arctic, Anchorage Oceanic, New York Oceanic, and Oakland Oceanic flight information regions.

[8]See, for example, Tactical Operations Committee, *Recommendations to Improve Operations in the Caribbean*, RTCA (July 2015) and Enhanced Surveillance Task Group of the NextGen Advisory Committee, *Enhanced Surveillance Capabilities in FAA Controlled Oceanic Airspace: Operational Need and Added Benefits,* RTCA (June 2017). RTCA is a standards development organization that works with FAA and was formerly known as the Radio Technical Commission for Aeronautics.

Figure 1: U.S. Oceanic Airspace with Selected Organized Track Systems



Flight Information Region[a]	Size of airspace (square miles)	Average number of flights per day[b]
Anchorage Oceanic & Arctic	2.75M	254
New York Oceanic	3.3M	626
Oakland Oceanic	18.6M	821

Organized Track Systems:

- **Central East Pacific Route System:** East–West routes between the U.S. West Coast and Hawaii
- **North Pacific Route System:** East-West routes between Alaska and Japan
- **North Atlantic Organized Track System:**[c] East-West routes between Europe and North America
- **Pacific Organized Track System:**[c] East–West routes between the U.S. West Coast and eastern Asia
- **West Atlantic Route System:** North–South routes from the U.S. East Coast to the Caribbean and South America and East–West routes from the U.S. East Coast to Europe

Sources: FAA and Map Resources. | GAO-19-532

[a]A flight information region (FIR) is an airspace of defined dimensions within which advice and information useful for the safe and efficient conduct of flights and notice of aircraft in need of search and rescue aid is provided.

[b]Average number of flights per day between July 2017 and June 2018.

[c]The North Atlantic Organized Track System and Pacific Organized Track System contain flexible routes, which change daily depending on weather patterns.

To fly through U.S. oceanic airspace, aircraft operators (e.g., airlines) file a flight plan, which includes the departure and arrival airports and the planned route (i.e., the path the aircraft plans to take to get to its destination).[9] Air traffic control may clear the flight plan as filed—with no changes—and/or makes changes to an aircraft's planned route during the flight.

Managing Air Traffic

To manage air traffic, air traffic controllers must be able to monitor an aircraft's position as it flies along its planned route. As we have previously reported, in domestic airspace, radar and ground-based Automatic Dependent Surveillance-Broadcast (ADS-B) technology provides this surveillance information.[10] Radar is a ground-based system that provides information on an aircraft's position to air traffic control facilities. Ground-based ADS-B uses equipment installed in aircraft (transmitters) to broadcast an aircraft's position, altitude, and other information to ground stations, which transmit the data to air traffic control facilities.[11] Surveillance information from radar and ADS-B is nearly instantaneous—allowing domestic air traffic controllers to effectively "see" where an aircraft is at all times. FAA manages radar and ground-based ADS-B infrastructure, in some cases through contracts. Through its contract with the provider of ADS-B services, FAA also pays for the cost of transmitting ADS-B messages from aircraft to air traffic control in domestic airspace.

However, in oceanic airspace, radar and ground-based ADS-B surveillance are not available.[12] As a result, oceanic air traffic controllers cannot "see" the aircraft they manage at all times. Instead, air traffic

[9]FAA, *Advisory Circular 91-70B, Oceanic and Remote Continental Airspace Operations* (Washington, D.C.: Oct. 4, 2016).

[10]GAO, *Aviation Safety: Proposals to Enhance Aircraft Tracking and Flight Data Recovery May Aid Accident Investigation, but Challenges Remain*, GAO-15-443 (Washington, D.C.: Apr. 16, 2015).

[11]As required by FAA regulation detailed in 14 C.F.R. §§ 91.225 and 91.227, aircraft using designated classes of airspace within the U.S. National Airspace System must be equipped with an ADS-B transmitter by January 2020. These transmitters will be used by FAA to provide another layer of surveillance information in addition to radar.

[12]FAA, *Advisory Circular 91-70B*.

Future Air Navigation System (FANS) Equipage in U.S. Oceanic Airspace

By 2020, FAA estimates that about 80 percent of aircraft flying in U.S. airspace above the Atlantic Ocean will be equipped with FANS as will 84 percent of aircraft flying in U.S. airspace above the Pacific Ocean. However, FANS equipage varies within these airspaces. In the New York flight region, specifically along the West Atlantic Route System, FAA estimates that by 2020 the FANS equipage rate will be 66 percent—lower than other sectors of Atlantic airspace. Similarly, in the Oakland flight region, along the Central East Pacific Route System, FAA estimates that by 2020 the FANS equipage rate will be 75 percent—lower than found in other sectors of Pacific airspace.

Source: FAA. I GAO-19-532.

controllers receive reports on an aircraft's position[13] from a radio operator who receives verbal updates from pilots using a high frequency radio or automatically through a technology called Future Air Navigation System (FANS):[14]

- High frequency radio allows pilots to speak with a third-party radio operator and share surveillance information via spoken position reports at mandatory reporting points. The radio operator then relays position reports as a data message to air traffic controllers.
- FANS includes a communication system—Controller Pilot Data Link Communications (CPDLC)—and a surveillance system—Automatic Dependent Surveillance-Contract (ADS-C). CPDLC allows pilots and air traffic controllers to communicate directly by exchanging text-based messages.[15] Through ADS-C, air traffic control can request position reports and specify their frequency as well as the information they should include. As we have previously reported, position reports sent through ADS-C can transmit at defined time intervals, when specific events occur such as pilot deviation from the planned route, or at the request of air traffic control.[16] ADS-C reports sent at a defined time interval are called periodic reports—in U.S. oceanic airspace these are typically sent every 10 to 14 minutes.

As detailed in an industry report, aircraft operators pay to use the satellite communication networks required to transmit communication and

[13]As detailed in FAA Advisory Circular 91-70B, all position reports transmitted in U.S. oceanic airspace, regardless of communication or surveillance technology, must contain the time and altitude at the aircraft's current position (latitude and longitude), expected arrival time at the next waypoint and the identity of the ensuing waypoint.

[14]ICAO requires that, at a minimum, aircraft operating over oceans must have a functioning two-way radio to communicate with the appropriate air traffic control unit. FAA requires scheduled commercial air carriers to carry certain communication and navigation equipment for extended over-water operations. For example, these aircraft operators must have at least two independent long-range navigation systems and at least two independent long-range communication systems to communicate with at least one appropriate station from any point on the route.

[15]In some cases, aircraft may be equipped with FANS (meaning both CPDLC and ADS-C) but the aircraft operator does not use ADS-C to issue position reports to air traffic control. In this scenario, a flight crew would use CPDLC, the communication system, to send a position report to air traffic control as the aircraft passes a waypoint.

[16]GAO-15-443.

surveillance information to air traffic control in oceanic airspace.[17] In addition, aircraft operators are responsible for the cost of equipping their aircraft with communication, navigation, and surveillance equipment.

To help them manage oceanic airspace, U.S. air traffic controllers use a computer system called Advanced Technologies and Oceanic Procedures (ATOP). ATOP is a flight data processing system that controllers use at their workstations. It provides oceanic air traffic controllers with several automated tools to assist in maintaining aircraft at safe distances from one another, coordinate with air traffic controllers in other flight regions, and facilitate controller-pilot communication through CPDLC, among other things. ATOP incorporates information from aircraft flight plans and position reports allowing controllers to monitor an aircraft's progress, ensure it is following the route cleared by air traffic control, and to continually check for any potential conflicts between aircraft flying through their area of control, i.e., aircraft that could get too close to one another.

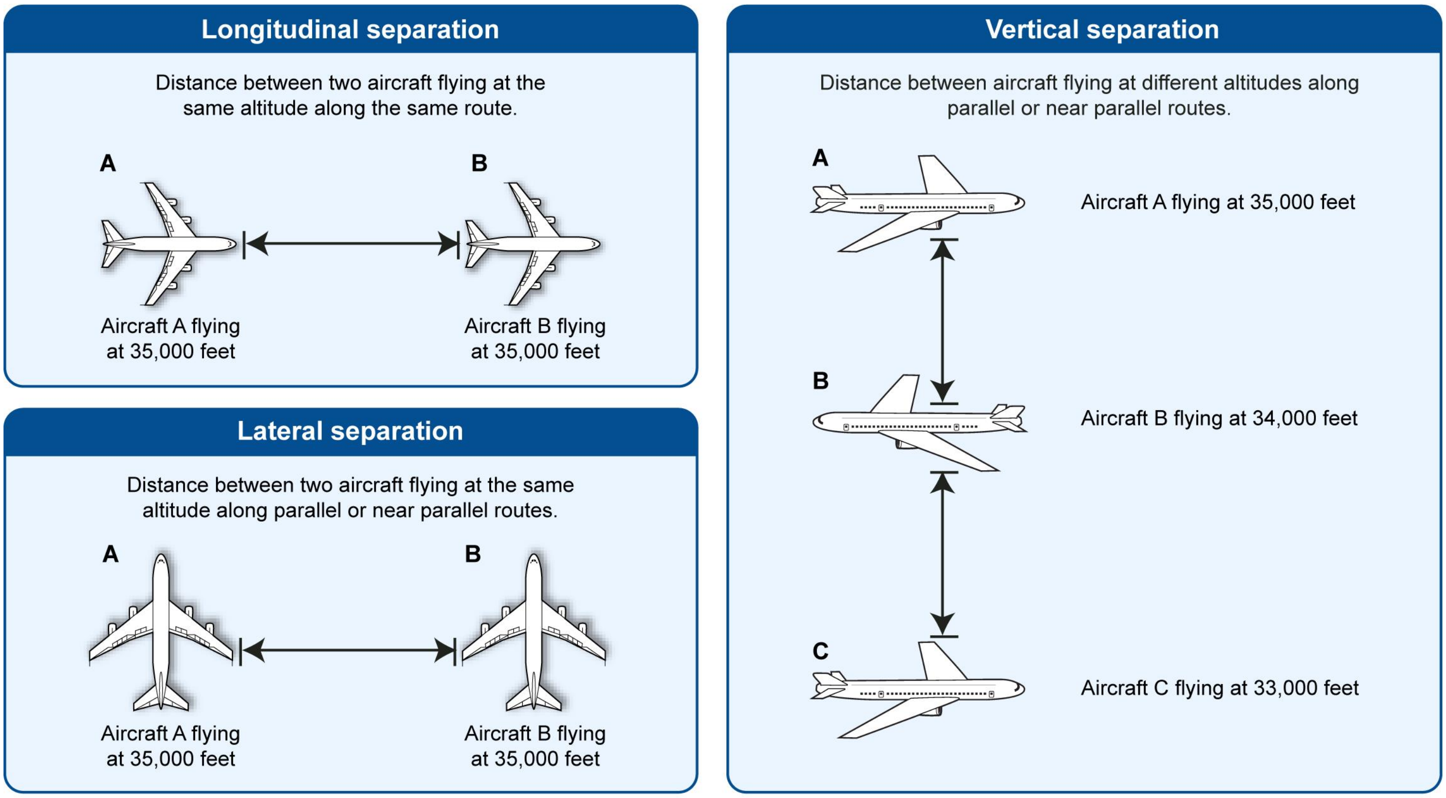
Oceanic Separation Standards

Separation standards—the minimum distances required between aircraft—help ensure that aircraft do not collide with one another. As illustrated in figure 2, separation standards dictate the minimum required longitudinal, lateral, and vertical distance between aircraft.[18]

[17] See, for example, Enhanced Surveillance Task Group of the NextGen Advisory Committee, *Enhanced Surveillance Capabilities in FAA Controlled Oceanic Airspace: Operational Need and Added Benefits,* RTCA (June 2017).

[18] In this report, we will focus on lateral and longitudinal separation standards. For more detail on these separation standards, see app. II.

Figure 2: Examples of Aircraft Separation



Source: GAO analysis of FAA documents. | GAO-19-532

Nautical Mile

A nautical mile is a unit of measure based on the circumference of the earth. It is slightly more than a land measured mile (1 nautical mile = 1.15 land measured miles). Nautical miles are used for navigating the sea and air.

Source: Merriam-Webster Dictionary I GAO-19-532.

The International Civil Aviation Organization (ICAO) publishes minimum separation standards for oceanic airspace. Using ICAO separation standards as the minimum, FAA sets the separation standards and aircraft requirements that are used in U.S. oceanic airspace.[19] Currently, the minimum distance that must be maintained between aircraft in U.S. oceanic airspace is 30 nautical miles lateral and 30 nautical miles longitudinal. To be eligible for this U.S. oceanic minimum separation standard, an aircraft must be equipped with FANS, in addition to meeting

[19]FAA, *Order JO 7110.65X,* Air Traffic Control, Effective Date: Oct. 12, 2017.

other communication, navigation, and surveillance requirements.[20] For aircraft without FANS, the minimum distance required between aircraft is larger, at least 50 nautical miles lateral and approximately 80 nautical miles longitudinal.

While requiring more distance between aircraft helps ensure safety, it means less airspace capacity and may result in fewer direct and fuel-efficient routes. To maintain the required separation distance between aircraft, air traffic control may instruct an aircraft—either before or during flight—to fly at an altitude or along a route that is not the most efficient for that aircraft in terms of flight time or fuel usage. For example, aircraft spaced 50 nautical miles apart laterally and longitudinally are less likely to be able to fly at a fuel-efficient altitude (e.g., 38,000 feet) as fewer aircraft will fly at that altitude, especially in congested airspace. In contrast, when aircraft are spaced 30 nautical miles apart laterally and longitudinally, more aircraft can fly at fuel-efficient altitudes.

FAA may adopt ICAO's minimum separation standards for the oceanic airspace it manages or it can adopt standards that require aircraft to fly farther apart than ICAO's minimum standards. For example, ICAO published the minimum separation standard for 30 nautical miles longitudinal in 2002.[21] FAA began applying these minimum separation standards in the Oakland Oceanic flight region in 2007, in the Anchorage Oceanic flight region in 2012, and in the New York Oceanic flight region in 2013.

In 2016, ICAO published a new minimum separation standard, which allows a minimum lateral distance of 23 nautical miles. FAA has not yet adopted the 23 nautical mile lateral standard. Since 2012, ICAO has worked to develop new minimum separation standards for oceanic airspace that require even less distance between properly equipped

[20]To be eligible to fly at the current minimum separation distance, aircraft must meet communication, navigation, and surveillance equipment and performance requirements. In March 2018, FAA officials told us the agency implemented Performance Based Communication and Surveillance requirements across U.S. oceanic airspace. In addition to meeting equipage requirements, aircraft must also show that their equipment meets communication and surveillance performance requirements. The required communication performance is that with a 99.9 percent probability a communication transaction between an aircraft and a controller will be completed in less than 240 seconds. The required surveillance performance is that there is a 99 percent probability that information sent from aircraft to air traffic control is received in 180 seconds or less.

[21]ICAO, Document 4444, Amendment 1 to the 14th edition (Nov. 28, 2002).

aircraft. These new minimum separation standards are based on improved surveillance capabilities, with aircraft using space-based ADS-B potentially eligible to use one set of reduced minimum separation standards (19 nautical miles lateral and 17 nautical miles longitudinal) and aircraft using enhanced ADS-C potentially eligible to use a different set of minimum separation standards (23 nautical miles lateral and 20 nautical miles longitudinal). These new minimum separation standards are undergoing review with final approval expected in 2020.[22]

Enhanced Surveillance Technologies

FAA's Advanced Surveillance Enhanced Procedural Separation (ASEPS) program, which is part of FAA's Air Traffic Organization, was tasked with examining how to increase the efficiency and capacity of operations in U.S. oceanic airspace using enhanced surveillance technologies.[23] In fiscal years 2015 through 2018, congressional committees directed FAA to accelerate its evaluation of space-based ADS-B and provided funding for that purpose.[24] In response, the ASEPS program, among other things, evaluated and compared the costs and benefits of two technologies that could improve surveillance capabilities in U.S. oceanic airspace—

[22]Throughout this report, we refer to "new minimum separation standards." As described above, the new minimum separation standards we are referring to include a standard (23 nautical mile lateral) that has been published by ICAO but not yet adopted by FAA for use in U.S. oceanic airspace and proposed standards (including the 20 nautical mile longitudinal, 19 nautical mile lateral, and 17 nautical mile longitudinal standards) that are undergoing review and expected to be published by ICAO in 2020. We refer to these standards as "new" because none is currently being used in U.S. oceanic airspace.

[23]The Air Traffic Organization is the operational arm of the FAA. It is responsible for providing air navigation services to all U.S. airspace.

[24]See, for example, the Joint Explanatory Statement accompanying the Consolidated Appropriations Act, 2018 in 164 Cong. Rec. H2874, No. 50, Book III, Mar. 22, 2018; Joint Explanatory Statement accompanying the Consolidated Appropriations Act, 2017, 76 Cong. Rec. H4081, Book III, May 3, 2017; Joint Explanatory Statement accompanying the Consolidated Appropriations Act, 2016, Comm. Print, 98-369, 114th Congress, 2nd Sess., p.1768; and Joint Explanatory Statement accompanying the Consolidated and Further Continuing Appropriations Act, 2015, 160 Cong. Rec. H9977, No. 151, Book II, Dec. 11, 2014.

enhanced ADS-C and space-based ADS-B.[25] Following are descriptions of how these enhanced surveillance technologies work:

- **Enhanced ADS-C.** Uses the same ADS-C technology already installed on FANS-equipped aircraft, but ATOP would request that automatic position reports be sent more frequently to air traffic control.[26] Aircraft equipped with ADS-C and transmitting position reports every 3.2 minutes would be eligible for ICAO's proposed minimum separation standard of 20 nautical miles longitudinal. ICAO's 23 nautical miles lateral separation standard, published in 2016, does not require more frequent ADS-C position reports.[27]
- **Space-based ADS-B.** Uses low-earth orbiting satellites to capture automatic reports broadcast by ADS-B transmitters installed on aircraft, which will be required for aircraft flying at certain altitudes in domestic U.S. airspace by 2020.[28] ADS-B messages are to be received by air traffic control about every 8 seconds. Aircraft equipped with ADS-B transmitters using the space-based ADS-B system and also equipped with required communication and navigation technologies,[29] would meet the eligibility requirements for ICAO's

[25]According to FAA officials, this funding was used to support the analysis of space-based ADS-B and enhanced ADS-C and program office costs; FAA's participation in the ICAO Separation and Airspace Safety Panel, which developed new minimum separation standards for oceanic airspace; and enhancements to ATOP to enable the adoption of new minimum separation standards. For a description of FAA's investment process and a timeline of the ASEPS program's progress through this process, see app. III.

[26]Currently, ADS-C reporting rates of 10 minutes are required for aircraft to be eligible for the current minimum separation standards of 30 nautical miles longitudinal in U.S. oceanic airspace.

[27]In addition to meeting surveillance requirements, to be eligible for the 23 nautical mile lateral and 20 nautical mile longitudinal standard, aircraft must also meet navigation and communication requirements. See app. II for more details.

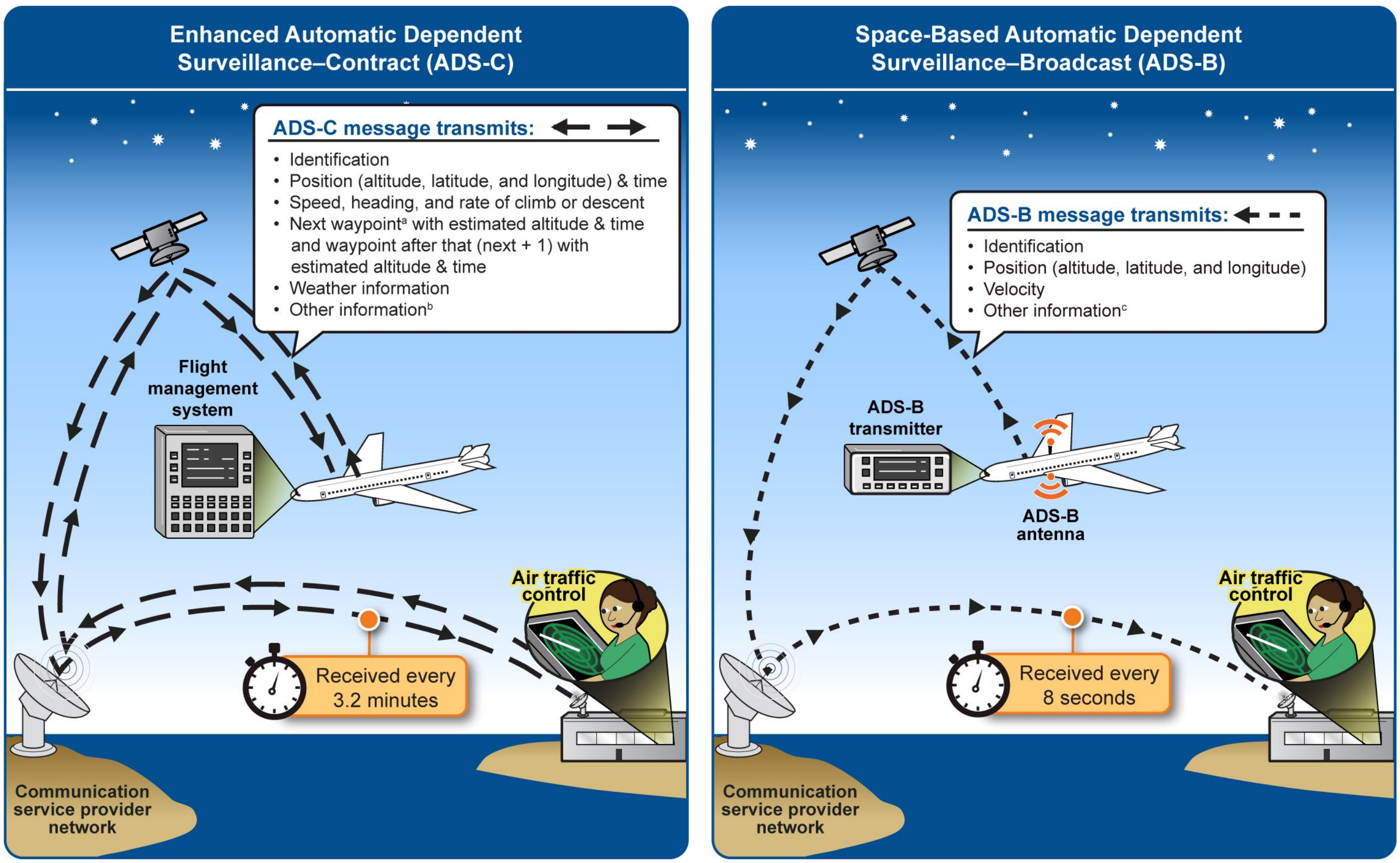
[28]14 C.F.R. §91.225. For aircraft operating in airspace over the U.S., including airspace over the waters within 12 nautical miles of the coast of the 48 contiguous states and flying above 18,000 feet (Class A airspace), an ADS-B transmitter—1090MHz Extended Squitter (1090ES)—must be installed. Aircraft operating below 18,000 feet may use the 978MHz Universal Access Transceiver. Space-based ADS-B is compatible with the 1090ES ADS-B transmitter. FAA data as of May 2019 show that over 83,000 U.S. aircraft have equipped with ADS-B equipment out of an estimated 241,000 aircraft that will need to equip by the 2020 deadline. In 2018, the DOT Office of Inspector General started a review looking at, among other topics, equipage rates for ADS-B and FAA's and aircraft operators' plans to meet the 2020 ADS-B equipage deadline.

[29]See app. II for more details on the communication, navigation, and surveillance requirements an aircraft must meet to be eligible for the 19 nautical mile lateral and 17 nautical mile longitudinal separation standards.

proposed minimum separation standards of 19 nautical miles lateral and 17 nautical miles longitudinal.[30]

As shown in figure 3, enhanced ADS-C and space-based ADS-B use similar transmission networks but relay different information at different time intervals to air traffic control.

Figure 3: Illustration of Data Transmissions between Air Traffic Control and Enhanced Surveillance Technologies in Oceanic Airspace



Source: GAO analysis of Aireon, FAA, International Civil Aviation Organization (ICAO), and Inmarsat documents. | GAO-19-532

[a]Waypoints are pre-determined geographical positions that define aircraft routes.

[b]Other information in an ADS-C message includes more information on an aircraft's navigational intent.

[30]See app. II for more details on the proposed minimum separation standards enabled by space-based ADS-B.

[c]Other information in an ADS-B message includes indications of the mode and operability of collision avoidance systems, of the accuracy of navigation readings, and if the flight crew has identified an emergency, radio communication failure, or unlawful interference.

To compare these options, FAA prepared a business case analysis that estimated the costs to the agency and aircraft operators, identified safety benefits from enhanced surveillance, and identified and calculated the value of operational efficiency benefits from using reduced minimum separation standards enabled by enhanced ADS-C and space-based ADS-B. For more detail on the costs and benefits included in FAA's business case analysis, see appendix IV. FAA used this business case analysis to inform its decision on which enhanced surveillance technology to use to support new minimum separation standards.

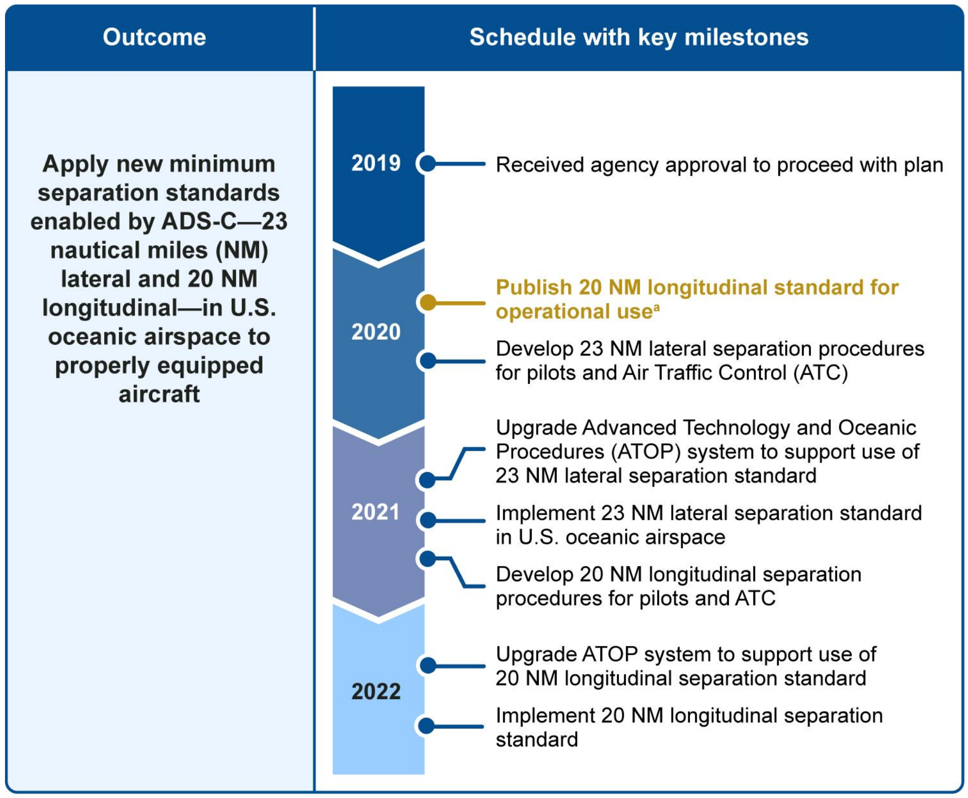
FAA Is Implementing New Oceanic Separation Standards in the Near Term and Will Study Options to Enhance Surveillance

FAA is implementing new minimum separation standards supported by enhanced ADS-C in U.S. oceanic airspace. FAA does not plan to use space-based ADS-B in U.S. oceanic airspace; instead, the agency intends to study how to use space-based ADS-B in other U.S. airspace over the next 5 years. According to FAA, this approach is driven by its analysis of the costs and benefits of each enhanced surveillance technology and the safety and operational challenges of using space-based ADS-B in U.S. oceanic airspace.

FAA Intends to Implement New Minimum Separation Standards Using Enhanced ADS-C in U.S. Oceanic Airspace By 2022

According to FAA officials and based on project status reports, FAA is implementing new minimum separation standards in U.S. oceanic airspace that are supported by enhanced ADS-C. The agency plans to apply these standards in all sectors of U.S. oceanic airspace by 2022, as shown in figure 4. Specifically, FAA will begin operational use of the 23 nautical mile lateral separation standard in U.S. oceanic airspace in 2021 and the 20 nautical mile longitudinal separation standard in 2022.

Figure 4: Federal Aviation Administration's Schedule with Key Milestones to Implement New Minimum Separation Standards Supported by Enhanced Automatic Dependent Surveillance-Contract (ADS-C)



Source: GAO analysis of FAA documents. | GAO-19-532

[a]The International Civil Aviation Organization (ICAO) is responsible for publishing this standard.

In April 2019, FAA executives approved a schedule and funding for the implementation of these new minimum separation standards (i.e., 23 nautical miles lateral and 20 nautical miles longitudinal) in U.S. oceanic airspace using enhanced ADS-C. To implement these new standards, FAA officials are upgrading ATOP and working through a review process required to change minimum separation standards in U.S. oceanic airspace. This review process involves 18 milestones, including safety assessments, coordinating with industry and international participants, and developing procedures and training materials for pilots and air traffic controllers.[31]

[31]See app. V for all 18 critical milestones of the review process required for changes to separation standards in oceanic airspace.

According to FAA officials, the costs and benefits of pursuing this approach—using enhanced ADS-C to support the adoption of new minimum separation standards, i.e., 23 nautical miles lateral and 20 nautical miles longitudinal—drove this decision. Specifically, FAA found that the benefits to airspace users of using enhanced ADS-C to enable new minimum separation standards, such as improved access to fuel-efficient altitudes, outweighed, by 2 to 1, the total costs, including FAA's costs to upgrade ATOP and the aircraft operators' data costs due to more ADS-C position reports.[32]

In addition, FAA officials said that although new minimum separation standards can provide benefits to airspace users overall, the current minimum separation standards support safe operations for current and anticipated levels of air traffic in U.S. oceanic airspace. Officials noted that the benefits to airspace users of new minimum standards are contingent on the communication, navigation, and surveillance capabilities of aircraft in an airspace and the frequency of disruptive weather patterns. According to FAA officials and air traffic controllers we spoke with, the current minimum separation standards (i.e., 30 nautical miles lateral and longitudinal) are rarely used as the density of aircraft traffic in U.S. oceanic airspace does not require such close spacing. In areas of U.S. oceanic airspace with higher traffic volumes, such as along the West Atlantic Route System and the Central East Pacific Route System, the number of aircraft without FANS and the frequency of disruptive weather patterns often prevent air traffic controllers from applying current minimum separation standards. Officials noted that they are also implementing the new minimum separation standards to harmonize with adjacent air navigation service providers.

FAA's ability to implement these new minimum separation standards (i.e., 23 nautical miles lateral and 20 nautical miles longitudinal) in their documented time frames depends on the success of planned ATOP upgrades. For example, FAA officials and air traffic controllers we spoke to told us that there is a current limitation in ATOP that under certain circumstances, air traffic controllers cannot rely on the system to ensure that minimum longitudinal separation distances are maintained. As a

[32]The benefit to cost ratio cited above is based on the risk-adjusted costs and risk-adjusted benefits for enhanced ADS-C presented in the August 2018 Final Business Case for Surveillance and Broadcast Services ASEPS Phase 1. See app. IV for more details on the costs, benefits, and assumptions used in FAA's business case analysis of enhanced ADS-C.

result, air traffic controllers cannot grant aircraft flying at the current minimum longitudinal separation distance their requests to deviate from their planned route for reasons such as avoiding disruptive weather or turbulence.[33] Representatives of the union that represents FAA air traffic controllers told us this limitation must be resolved before new separation standards (i.e., 23 nautical miles lateral and 20 nautical miles longitudinal) can be safely applied. FAA officials told us that they have developed an ATOP software upgrade that could resolve this issue; the upgrade is scheduled to occur in 2021. However, if this upgrade does not resolve the issue or it takes longer to resolve than planned, implementation of the new minimum separation standards could be delayed.

Due to Cost, Safety, and Operational Concerns, FAA Plans to Study Space-Based ADS-B in Other U.S. Airspace

Cost, Safety, and Operational Concerns

According to FAA officials, the cost of space-based ADS-B was a major factor in their decision not to use this technology in U.S. oceanic airspace. FAA's initial business case analysis found that the costs of using space-based ADS-B to enable reduced separation outweighed the benefits. Specifically, the estimated subscription costs to access the data collected by space-based ADS-B and needed upgrades to ATOP outweighed the estimated benefits to airspace users by 6 to 1.[34] As mentioned above, according to FAA officials, current minimum separation standards allow safe operations for current and anticipated levels of air traffic in U.S. oceanic airspace. Therefore, without a positive business case (i.e., benefits are larger than the costs), FAA officials decided they could not pursue this enhanced surveillance option for U.S. oceanic airspace.

[33]In these cases, if the pilot determines it is necessary to deviate to avoid disruptive weather or turbulence, the pilot can still do so after notifying air traffic control of their intention and then following oceanic procedures for such an action.

[34]The cost to benefit ratio cited above is based on the risk-adjusted costs and risk-adjusted benefits for space-based ADS-B presented in the September 2017 Initial Business Case for Surveillance and Broadcast Services ASEPS. In FAA's business case analysis on enhanced surveillance options, several scenarios were included that modelled different levels of aircraft use of space-based ADS-B. Even when assuming that all properly equipped aircraft in U.S. oceanic airspace were using a space-based ADS-B service, the estimated costs of using space-based ADS-B outweighed the estimated benefits. See app. IV for more details.

FAA officials we interviewed also had safety concerns about using space-based ADS-B to manage reduced separation in U.S. oceanic airspace at this time. Specifically, FAA officials told us the operational considerations for most of the U.S. oceanic airspace were not reflected in the data used by ICAO to model the safety of these standards—air traffic control response times and rates of approved and unapproved aircraft weather deviations. For example, the ICAO panel responsible for analyzing the safety of the proposed minimum separation standards enabled by space-based ADS-B used data from the North Atlantic on the number of times aircraft deviate without authorization from their expected flight plan due to weather conditions. According to FAA officials, other oceanic regions—especially in U.S. oceanic airspace—experience a higher frequency of these deviations. As a result, FAA officials do not plan to use the new minimum separation standards enabled by space-based ADS-B (i.e., 19 nautical miles lateral and 17 nautical miles longitudinal) until FAA can further address how to implement these standards in U.S. oceanic airspace.

FAA officials we interviewed also had operational concerns about using space-based ADS-B with ATOP to manage separation between aircraft in U.S. oceanic airspace. Specifically, FAA officials told us that ATOP is designed to use information in ADS-C position reports—i.e., an aircraft's current location, the next waypoint the aircraft will pass and at what time, and the subsequent waypoint the aircraft will pass—to determine potential conflicts in aircraft flight paths. Without this information, ATOP would not receive the data it uses to detect conflicts within the next 2 hours of a flight, according to FAA officials. ADS-B messages do not include this information and therefore, space-based ADS-B would not replace ADS-C in U.S. oceanic airspace.

Due to these cost, safety, and operational concerns with using space-based ADS-B to enable reduced separation, the ASEPS program deferred a decision, originally scheduled for September 2018, on whether to invest in using space-based ADS-B in U.S. oceanic airspace. FAA officials said that while they have not yet found a positive business case for using space-based ADS-B in U.S. oceanic airspace, they will further study space-based ADS-B in U.S. offshore and oceanic airspace. According to FAA officials, they expect further study to identify additional benefits and resolve operational challenges to using space-based ADS-B.

FAA's Plans to Study Space-Based ADS-B in U.S. Offshore and Oceanic Airspace

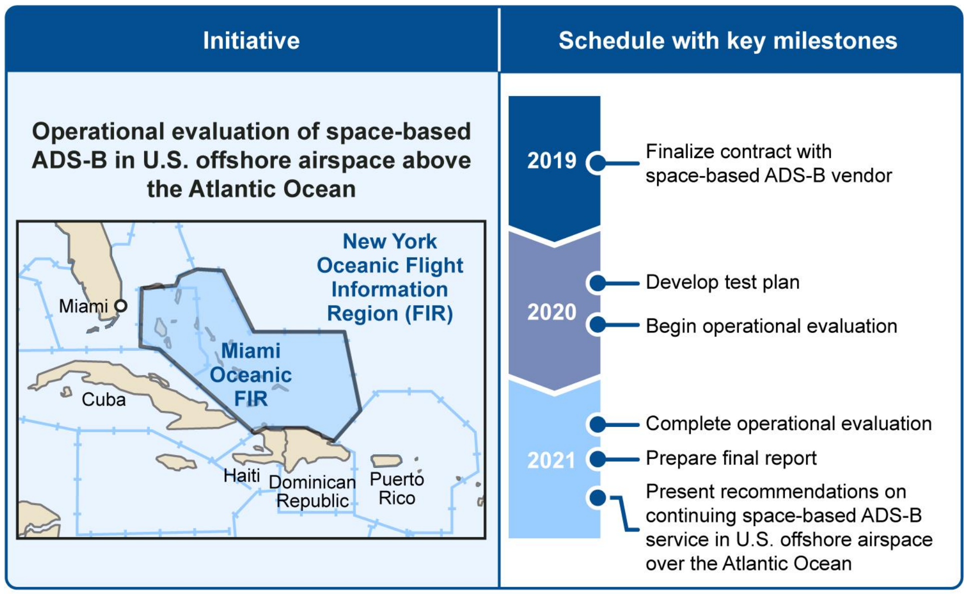
FAA officials and documents indicate that the agency has near-term, medium-term, and long-term plans with goals, milestones, and time frames to evaluate how to use space-based ADS-B in U.S. airspace over the next 5 or more years. These plans include an operational evaluation and other studies to assess the uses and benefits of space-based ADS-B in U.S. airspace. FAA officials told us they expect to use findings from the near-term operational evaluation to inform medium-term and long-term plans.

Near Term

According to FAA officials and documentation, the ASEPS program intends to conduct an operational evaluation of space-based ADS-B in U.S. offshore airspace managed by controllers based in Miami, as shown in figure 5.[35]

[35]As explained above, U.S. oceanic airspace includes the Anchorage Arctic, Anchorage Oceanic, New York Oceanic, and Oakland Oceanic flight regions, which are managed by U.S. air traffic controllers at their respective air route traffic control centers. The Miami Oceanic Flight Information Region—which is under the control of the Miami Air Route Traffic Control Center—is classified as "offshore" airspace. Offshore airspace is international airspace that falls between domestic airspace and oceanic airspace to which domestic air traffic control procedures, including domestic separation standards, may be applied.

Figure 5: Federal Aviation Administration's Schedule with Key Milestones for an Operational Evaluation of Space-Based Automatic Dependent Surveillance-Broadcast (ADS-B) in U.S. Offshore Airspace



Source: GAO analysis of FAA documents. | GAO-19-532

Note: The Miami Oceanic Flight Information Region (FIR)—which is under the control of the Miami Air Route Traffic Control Center—is classified as "offshore" airspace. Offshore airspace is international airspace that falls between domestic airspace and oceanic airspace to which domestic air traffic control procedures, including domestic separation standards, may be applied.

FAA officials told us that this operational evaluation will assess space-based ADS-B with the computer system used by domestic air traffic controllers—the En Route Automation Modernization (ERAM) system. The operational evaluation will also focus on how to use space-based ADS-B in the heavily travelled airspace between the U.S. East Coast and islands in the Caribbean and assess potential benefits. As detailed by FAA officials, a radar that is located on Grand Turk Island[36] provides critical data to U.S. air traffic controllers and enables the use of domestic separation standards of 5 nautical miles in this airspace. When this radar is out of service, which happens on a regular basis, aircraft traversing the airspace between Florida and Puerto Rico must be spaced using oceanic separation standards (e.g., separation distances of 30 nautical miles or greater). According to an industry report and FAA officials, this situation

[36]Grand Turk Island is an island in the Turks and Caicos Islands. The Turks and Caicos Islands is a self-governing overseas territory of the United Kingdom. FAA does not operate or maintain this radar.

leads to re-routes and delays, which negatively affect airline operations.[37] Using space-based ADS-B as a back-up surveillance system would ensure that even when the Grand Turk radar fails, U.S. air traffic control can continue to manage air traffic using domestic separation standards.

In 2021, once the operational evaluation is complete, the ASEPS program expects to make recommendations to FAA executives on how to use space-based ADS-B in the Miami oceanic flight region, in addition to other areas. FAA officials also said that this evaluation will allow the agency to test space-based ADS-B in an operational environment and that the findings can inform its medium-term and long-term plans for using space-based ADS-B. The use of space-based ADS-B in this airspace could also result in more direct routes between the U.S. East Coast and islands in the Caribbean.

Medium Term

According to FAA officials and documentation, the ASEPS program expects to study additional potential benefits of space-based ADS-B over the next 3 to 5 years. These medium-term initiatives are expected to:

- **Analyze the use of space-based ADS-B for contingency operations in U.S. airspace**. This study would define where space-based ADS-B can be used to provide surveillance capabilities when ground-based infrastructure (e.g., radar) is unavailable, such as after a hurricane. As part of this plan, the ASEPS program would also identify upgrades that would be needed for air traffic control computer systems to support using space-based ADS-B.
- **Analyze operational challenges in U.S. oceanic airspace and potential solutions**. This study of U.S. oceanic airspace would include a data-driven analysis of the use and constraints on the use of user-preferred routes by aircraft in U.S. oceanic airspace. In addition to providing information on potential inefficiencies in oceanic airspace operations, the analysis will cover how to mitigate potential safety hazards related to the use of space-based ADS-B in the oceanic environment and the requirements for future upgrades to ATOP to support the use of space-based ADS-B.

[37]Tactical Operations Committee, *Recommendations to Improve Operations in the Caribbean*, RTCA (July 2015).

According to FAA officials, both medium-term initiatives would result in recommendations for consideration by FAA executives in 2021. Using space-based ADS-B for contingency operations could lead to updated air traffic control procedures and computer upgrades; however, this would depend on the results of the analysis and the approval of FAA executives. The analysis of user-preferred routes in oceanic airspace could lead to recommendations on how to optimize route systems and how to use space-based ADS-B to support the use of user-preferred routes.

Long Term

According to FAA officials and documentation, using space-based ADS-B to enable the use of new minimum separation standards in U.S. oceanic airspace will be reviewed and evaluated over the next 5 or more years. This long-term initiative will use information learned through the near-term and medium-term plans. As part of this initiative, the ASEPS program intends to investigate options for enhanced communication technologies and encourage industry development of these technologies. As with the medium-term initiatives, the ASEPS program expects to make recommendations to FAA executives on how to proceed with this plan in 2021. Based on the results of this initiative, program officials told us they could start preparing for an investment decision on using space-based ADS-B in oceanic airspace to enable the use of new minimum separation standards in 2025 or later.

Selected Aviation Stakeholders Support FAA's Overall Approach to Enhancing Surveillance and Identified Expected Benefits from Reducing Separation

Most Selected Airlines Support FAA's Overall Approach to Enhancing Surveillance

Most (11 of 14) of the selected airlines we interviewed and surveyed support FAA's approach to enhance surveillance capabilities in U.S. oceanic airspace by pursuing enhanced ADS-C and adopting new minimum oceanic separation standards of 23 nautical miles lateral and 20 nautical miles longitudinal in the near term.[38] Most (12 of 14) also support continuing to evaluate how to use space-based ADS-B in oceanic airspace. Of those selected airlines that did not support FAA's approach, the reasons included concern that using enhanced surveillance technologies will increase operator costs with no clear benefits and that FAA is prioritizing enhanced ADS-C over space-based ADS-B despite the safety and technological advances the latter would enable.

While most selected airlines (12 of 14) were satisfied or very satisfied with how FAA manages the safety of U.S. oceanic airspace,[39] most noted the need to improve operational efficiency in this airspace. Specifically, many selected airlines (10 of 14) reported experiencing operational inefficiencies, including not being able to fly at fuel-efficient altitudes. Many of these airlines (9 of 10) view adopting new minimum separation standards as a way to address these inefficiencies. Other aviation stakeholders, including the unions representing FAA air traffic controllers and commercial airline pilots, also see the need to enhance surveillance and adopt new minimum separation standards to ensure that U.S. oceanic airspace remains efficient as international air traffic grows.

[38]See app. I for more information on the airlines we spoke with and how we selected them.

[39]The two airlines that indicated they were dissatisfied with how FAA manages safety in U.S. oceanic airspace did not mention safety concerns. Instead, they focused on inefficiencies in oceanic airspace that affect their operations.

Selected Airlines Identified Expected Benefits from FAA's Implementation of New Minimum Oceanic Separation Standards

Selected airlines identified several benefits they would expect to see from the implementation of new minimum oceanic separation standards, including improved access to fuel-efficient altitudes, redesigned organized track systems, and improved access to user-preferred routes.

Improved Access to Fuel-Efficient Altitudes

Most selected airlines (12 of 14) we surveyed view improved access to fuel-efficient altitudes as a benefit of reduced separation standards. Aircraft flying in controlled airspace cannot change altitudes (e.g., move from 36,000 feet to 38,000 feet) without air traffic control approval. With reduced minimum separation standards, air traffic control could grant more altitude change requests, allowing aircraft to more consistently fly at fuel-efficient altitudes. For example, representatives from one airline told us that an aircraft's ability to climb and descend as needed provides both safety and operational benefits. Other airline representatives also told us that the ability to fly at fuel-efficient altitudes results in savings on fuel costs.

Redesign of Organized Track Systems

Many selected airlines (9 of 14) think FAA should make changes to organized track systems once new minimum separation standards are adopted. These changes include reducing lateral separation between routes or removing the systems entirely to enable aircraft to fly user-preferred routes all the time.

- **Reduce lateral separation between the routes in organized track systems.** Currently, all organized track systems in U.S. oceanic airspace have routes spaced at least 50 nautical miles apart laterally. Several selected airlines (3) told us that they would expect FAA to take advantage of new reduced minimum separation standards by spacing routes more closely together. For example, representatives from one airline suggested spacing the routes in the West Atlantic Route System 30 nautical miles apart laterally—thus increasing the number of routes from 10 to 19 and significantly increasing airspace capacity. In a report prepared by the NextGen Advisory Committee's Enhanced Surveillance Task Group at the request of FAA, there was also support for taking advantage of new minimum separation standards enabled by enhanced surveillance to reduce the lateral separation between routes in the Central East Pacific Route System.[40]

- **Remove all organized track systems.** Several selected airlines (5 of 14) also viewed the adoption of new minimum separation standards as a step toward the removal of all organized track systems. Removing all organized track system routes would, by definition, mean aircraft operators could fly user-preferred routes optimized according to their preferences, such as fuel use and flight time. Air navigation service providers in Canada and the United Kingdom, which are responsible for managing the North Atlantic Organized Track System, told us that the use of space-based ADS-B and the proposed separation standards it supports (i.e., 19 nautical miles lateral and 17 nautical miles longitudinal), may lead to the end of published ATS routes for the North Atlantic Organized Track System.

Access to User-Preferred Routes

Many selected airlines indicated that current separation standards inhibit their ability to fly user-preferred routes (10 of 14) as well as their ability to fly the most efficient user-preferred routes (11 of 14). Many selected airlines (9 of 14) view more access to user-preferred routes or the ability to fly more efficient user-preferred routes as an expected benefit of new minimum separation standards. Several selected airlines (3 of 14) also told us that they no longer request to fly user-preferred routes in the airspace covered by the Central East Pacific Route System or along the West Atlantic Route System because these requests are denied or they are re-routed during the flight.

Selected airlines also noted the importance of understanding the costs, benefits, and timelines associated with the implementation of enhanced surveillance technologies in making their own investment decisions. Specifically, most selected airlines (11 of 14) told us that their decision to use an enhanced surveillance technology is contingent upon how much it will cost them to implement the technology—which can involve equipping aircraft and potentially paying subscription costs for the service—compared to the benefits airlines receive from the technology. For example, representatives from one airline told us that they are interested

[40]Enhanced Surveillance Task Group of the NextGen Advisory Committee, *Enhanced Surveillance Capabilities in FAA Controlled Oceanic Airspace: Operational Need and Added Benefits,* RTCA (June 2017).

in the benefits of space-based ADS-B and enhanced ADS-C, but before paying for new or additional surveillance services, they would need to have evidence that the benefits of these services would outweigh the costs. Specifically, the representatives would like to know to what extent enhanced surveillance, if at all, would result in the actual use of new minimum separation standards and the likelihood they would be able to fly the flight plan they filed. With this information, the airline representatives said the airline could determine whether they could realize cost savings or additional revenue, such as through adding flights to their schedules. Representatives from another airline told us they would like to know what FAA’s plan is for enhancing surveillance and enabling new minimum separation standards and to have assurance that FAA will stick to this plan.

FAA Is Taking Steps to Realize the Benefits of New Minimum Oceanic Separation Standards

According to FAA officials and documents, the agency’s approach addresses some of the efficiency benefits expected by airspace users.

- **Improved access to fuel-efficient altitudes.** FAA officials and air traffic controllers we spoke to expect the adoption of new minimum separation standards to offer efficiency benefits to airspace users through more consistent access to fuel-efficient altitudes. In a business case analysis, FAA estimated that this benefit would result in over $280 million in cost-savings for aircraft operators. According to air traffic controllers we spoke to, with new minimum separation standards they would be able to more frequently grant aircraft requests to access these altitudes.
- **Redesign of organized track systems.** When considering changes to organized track systems, FAA officials said they must balance benefits to airspace users with workload demands that would be placed on air traffic controllers. FAA officials told us they are currently redesigning the North Pacific Route System to take advantage of the 23 nautical mile lateral separation standard by reducing the lateral separation between tracks. According to FAA officials, this redesign, which is planned to be complete by 2021, could offer benefits to aircraft operators flying between Japan and Alaska, such as allowing air traffic to move more efficiently and with fewer restrictions on user-

preferred routes.[41] FAA officials told us that redesigning the North Pacific Route System is possible because of high FANS-equipage rates (over 95 percent) and the absence of disruptive weather patterns. However, according to FAA officials, they do not plan any changes to other organized track systems, such as the Central East Pacific Route System and the West Atlantic Route System, at this time because of aircraft equipage rates and weather patterns. In such areas, moving the routes closer together would prevent air traffic controllers from approving aircraft requests to deviate due to bad weather.

- **Access to user-preferred routes.** FAA officials differ with selected airline representatives on whether reduced separation standards would lead to increased access to user-preferred routes. According to FAA officials and documents, improved access to user-preferred routes requires an increase in aircraft equipped with FANS, not changes to the airspace. FAA officials also said that airlines can fly user-preferred routes in the Central East Pacific Route System and the West Atlantic Route System but also acknowledged that air traffic controllers often cannot grant access to user-preferred routes in these airspaces because of the volume of air traffic or disruptive weather patterns. Given the differing perspectives and limited data on user-preferred routes, in April 2019, FAA decided to engage a third-party research company to study the use of and access to user-preferred routes in U.S. oceanic airspace, to be completed in late 2021. Based on this study, FAA may investigate changes to U.S. airspace to address problems identified.

FAA identified venues to share and coordinate their enhanced surveillance plans, timelines, and expectations with aviation industry stakeholders. As previously noted, FAA's process for implementing changes to separation standards requires the agency to coordinate with and brief domestic and international aviation industry stakeholders. FAA officials also pointed to other venues where they plan to share information on these plans with airlines, including formal and informal working groups. Given the relatively early stages of the implementation of the 23 nautical mile lateral and 20 nautical mile longitudinal separation standards enabled by enhanced ADS-C, FAA has not yet completed this industry

[41]Currently, user-preferred routes are allowed across the North Pacific Route System. However, aircraft wanting to fly a user-preferred route must adhere to FAA requirements on for example, certain waypoints that must be included in a flight plan, restrictions on where an aircraft can join the North Pacific Route System, and altitude requirements.

outreach. The agency plans to coordinate with the aviation industry on the implementation of these separation standards by January 2021.

Selected Airlines and Other Aviation Stakeholders Raised Concerns about Two Possible Consequences of FAA's Approach to Enhanced Surveillance

International Leadership

Several selected airlines and other aviation stakeholders—representing pilots, commercial airlines, business aircraft operators, and general aviation—noted the importance of FAA taking advantage of technology advancements and benefits that space-based ADS-B can offer. For example, several (5) selected airlines view space-based ADS-B as a major advancement in oceanic surveillance. Representatives from one airline told us that FAA risks losing its position as a global leader if it does not move forward with space-based ADS-B and the reduced separation standards it enables.

According to FAA officials, the agency is a leading air navigation service provider as demonstrated by its use of advanced computer systems to apply minimum separation standards when possible, its role in developing ICAO's new minimum separation standards, and its plans to move forward with space-based ADS-B in a manner that best fits U.S. oceanic airspace needs.[42] FAA officials also pointed to other air navigation service providers, such as the Japan Civil Aviation Bureau, that are not currently planning to use space-based ADS-B.

Harmonization with Adjacent Flight Regions

Several selected airlines and other aviation stakeholders representing commercial and business airlines expressed concern that by not adopting enhanced surveillance and the minimum separation standards it enables, aircraft transitioning into and out of U.S. oceanic airspace could experience delays. Representatives of the Canadian and United Kingdom air navigation service providers, which began using space-based ADS-B and the new minimum separation standards it enables in 2019, told us that different separation standards between their oceanic airspace and

[42]The FAA Reauthorization Act of 2018, Pub. L. No. 115-254, § 562, requires FAA to identify and implement a strategy to advance near- and long-term uses of enhanced surveillance systems, such as space-based ADS-B; exercise leadership on setting global standards for the separation of aircraft in oceanic airspace; and ensure FAA's participation in analysis of trials using enhanced surveillance systems, as are planned in the north Atlantic.

U.S. oceanic airspace could lead to delays for aircraft as air traffic increases.[43] Specifically, as air traffic grows and air traffic controllers apply separation distances closer to the minimum standards, those flight regions with lower minimum standards will have to space out aircraft crossing into flight regions with higher minimum separation standards prior to an aircraft crossing a flight region boundary. This situation could lead to delays crossing flight region boundaries and less access to efficient routes across oceanic airspace.

FAA views other factors, such as the low volume of air traffic in some airspaces, the frequency of disruptive weather patterns, and the relatively low percentage of aircraft equipped with FANS in high volume airspaces, to contribute more to the operational efficiency of the oceanic airspace than the use of minimum standards. As previously noted, according to FAA officials and air traffic controllers, the current minimum separation standards for U.S. oceanic airspace (30 nautical miles lateral and longitudinal) are rarely used because of these factors. In addition, FAA officials told us that the difference between the separation standards FAA plans to adopt in U.S. oceanic airspace with enhanced ADS-C (23 nautical miles lateral and 20 nautical miles longitudinal) and the separation standards enabled by space-based ADS-B (19 nautical miles lateral and 17 nautical miles longitudinal) is unlikely to result in delays even as air traffic increases.

Other air navigation service providers in the Atlantic and Pacific Oceans are still assessing the costs and benefits of space-based ADS-B. For example, the Portuguese air navigation service provider told us they are still considering whether to use space-based ADS-B. In the Pacific Ocean, the Japanese air navigation service provider has not decided whether to use space-based ADS-B and therefore will not be adopting the minimum separation standards (19 nautical miles lateral and 17 nautical miles longitudinal) enabled by this technology. While the Japanese plan to adopt the 23 nautical mile lateral separation standard supported by enhanced ADS-C, they do not plan to adopt the 20 nautical mile longitudinal separation standard at this time.

[43]The air navigation service providers in Canada and in the United Kingdom share the management of the North Atlantic Organized Track System—the busiest track system in the world—that funnels traffic between Europe and North America. The proposed minimum separation standards enabled by space-based ADS-B are being used on a trial basis in the North Atlantic.

Agency Comments

We provided a draft of this report to the Department of Transportation (DOT) for review and comment. DOT responded by email and provided technical clarifications, which we incorporated into the report as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of the Department of Transportation, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-2834 or krauseh@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix VI.

Heather Krause
Director,
Physical Infrastructure Issues

Appendix I: Objectives, Scope, and Methodology

This report examines (1) the Federal Aviation Administration's (FAA) approach to enhancing surveillance capabilities to improve safety and efficiency in U.S. oceanic airspace and (2) selected aviation stakeholders' perspectives on FAA's approach to enhancing surveillance.

To address both of our objectives, we reviewed FAA and other aviation stakeholders' documents on the management and organization of U.S. oceanic airspace; the functionality and use of communication, navigation, and surveillance equipment in aircraft flying in U.S. oceanic airspace; and descriptions of the enhanced surveillance technologies that were being considered by FAA—space-based Automatic Dependent Surveillance-Broadcast (ADS-B) and enhanced Automatic Dependent Surveillance-Contract (ADS-C). Specifically, to understand how U.S. air traffic controllers manage oceanic airspace and the procedures aircraft operators must follow, we reviewed FAA Advisory Circulars on *Oceanic and Remote Continental Airspace Operations* (91-70B) and *Data Link Communications* (90-117) and FAA *Order JO 7110.65X*: Air Traffic Control.[1] We also reviewed a NextGen Advisory Committee report, *Enhanced Surveillance Capabilities in FAA Controlled Oceanic Airspace: Operational Need and Added Benefits,* that was prepared at the request of FAA on this topic, to understand the industry perspective on the need for enhanced surveillance in U.S. oceanic airspace and the costs and benefits of using space-based ADS-B.[2] To understand how space-based ADS-B and enhanced ADS-C would function, we interviewed representatives from Aireon, which offers the space-based ADS-B service, and Inmarsat, which provides the primary satellite communication network used by the providers of ADS-C services.

[1]FAA, *Advisory Circular 91-70B, Oceanic and Remote Continental Airspace Operations* (Washington, D.C.: Oct. 4, 2016); FAA, *Advisory Circular 90-117, Data Link Communications* (Washington, D.C.: Oct. 3, 2017); and FAA, *Order JO 7110.65,* Air Traffic Control, Effective Date: Oct. 12, 2017.

[2]Enhanced Surveillance Task Group of the NextGen Advisory Committee, *Enhanced Surveillance Capabilities in FAA Controlled Oceanic Airspace: Operational Need and Added Benefits,* RTCA (June 2017).

We also interviewed other aviation industry stakeholders, including trade associations representing aircraft operators and unions representing pilots, including Airlines for America, International Air Transport Association, National Air Carrier Association, National Business Aviation Association, Aircraft Owners and Pilots Association, Coalition of Airline Pilots Associations, and Air Line Pilots Association. These organizations were selected based on several factors: their inclusion in prior GAO reports, their role in the aviation industry, and recommendations from other industry stakeholders or FAA.

To examine FAA's approach to enhancing surveillance capabilities in U.S. oceanic airspace, we reviewed FAA documents and interviewed FAA officials. The documents we reviewed included those related to FAA's plans to modernize management of oceanic airspace, specifically T*he Future of the National Airspace System* (June 2016) and *National Airspace System Capital Investment Plan FY2018-2022.*[3] We also reviewed FAA's policy guidance on acquisitions and investment documents related to the Advanced Surveillance Enhanced Procedural Separation (ASEPS) program's planned investment decision on enhanced surveillance. These internal FAA documents included the ASEPS Concept of Operations, the Initial and Final Business Case Analyses, the Final Investment Decision Benefits Basis of Estimate, and a Safety Risk Management Assessment of space-based ADS-B and enhanced ADS-C. In reviewing the business case analysis, we did not independently evaluate the methodology or data sources used.

We interviewed FAA officials and program managers that are working on different elements of FAA's efforts to enhance surveillance in U.S. oceanic airspace. Within the Air Traffic Organization,[4] we interviewed officials from several offices, including the ASEPS program, which managed the evaluation of surveillance technologies; the Oceanic/Offshore Standards and Procedures Branch, which oversees air traffic operations in oceanic airspace such as facilitating changes to air traffic procedures and systems to enable the use of new technologies and new standards; and the Advanced Technologies and Oceanic Procedures Program Office, which oversees changes to the air traffic control

[3]See, FAA, *The Future of the NAS* (Washington, D.C.: June 2016) and FAA, *National Airspace System Capital Investment Plan FY2018-2022* (Washington, D.C.: Nov. 2017)

[4]The Air Traffic Organization is the operational arm of the FAA. It is responsible for providing air navigation services to all U.S. airspace.

computer system used to manage oceanic air traffic. We also interviewed FAA officials with the Flight Standards Service, which works to improve flight operations, standardization, and aviation safety across U.S. and international airspace systems. In addition, we interviewed the contractor who prepared FAA's business case analyses.

We interviewed FAA air traffic controllers at the Anchorage, New York, and Oakland air route traffic control centers, which are responsible for managing the flight information regions that comprise U.S. oceanic airspace. In addition, we conducted site visits to the New York and Oakland air route traffic control centers, where we observed air traffic controllers providing oceanic air traffic services. We also interviewed representatives from the National Air Traffic Controllers Association, which is the union representing FAA air traffic controllers. We also interviewed or received written responses from representatives of the air navigation service providers for oceanic airspace adjacent or close to U.S. oceanic airspace—Canada, Japan, Portugal, and the United Kingdom—to understand their plans to enhance surveillance capabilities.

To obtain selected aviation stakeholders' perspectives on FAA's approach to enhancing surveillance in U.S. oceanic airspace, we selected 10 U.S. and foreign commercial airlines using FAA data from fiscal year 2016 on the annual number of flights by airline in U.S. oceanic flight information regions–Anchorage Arctic and Oceanic, Oakland Oceanic, and New York Oceanic. Specifically, we selected the five airlines in each U.S. oceanic flight information region with the most annual flights. Some airlines were in the top five in more than one flight information region. All 10 airlines selected using this method were passenger airlines. We selected an additional passenger airline because it planned to begin service in U.S. oceanic airspace. We selected three large cargo airlines, based on tons of cargo transported, to ensure that the cargo airlines' perspective was represented. Of the 14 airlines we selected, we conducted semi-structured interviews with or received written responses to our questions from 13.

To obtain additional information from airline operators, we conducted a follow-up survey of the 14 selected airlines. The survey included questions on perceptions of the safety of FAA's management of U.S. oceanic airspace, operational inefficiencies experienced by airlines in U.S. oceanic airspace, effect of current separation standards on airlines' use of user-preferred routes, airlines' expectations of the benefits of reduced separation standards, and airlines' support for FAA's planned approach to enhance surveillance in oceanic airspace. We developed the survey based on our objectives and included topics not covered in our initial interviews. We pre-tested our survey with representatives of three of the 14 selected airlines. We conducted the survey between December 2018 and January 2019, and all 14 selected airlines completed the survey. For the complete list of airlines we interviewed and/or surveyed, see table 1.

Table 1: Selected Airlines GAO Interviewed or Surveyed

U.S. airlines	Foreign airlines
Alaska Airlines	Cathay Pacific
American Airlines	EVA Air
Atlas Air[a]	Iberia
Delta Air Lines	Korean Air
FedEx Express[a]	
Hawaiian Airlines	
JetBlue	
Southwest Airlines	
United Airlines	
UPS Airlines[a]	

Source: GAO. | GAO-19-532

[a]Cargo carrier

In this report, we use the following conventions in reference to information obtained from the 14 selected airlines: “several” is three to seven, “many” is eight to 10, and “most” is 11 to 13.

We conducted this performance audit from March 2018 to July 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Current and Proposed Separation Standards for Oceanic Airspace

Current and Proposed Minimum Separation Standards for Oceanic Airspace

The International Civil Aviation Organization (ICAO) publishes minimum separation standards and related eligibility requirements for oceanic airspace. Air navigation service providers, such as the Federal Aviation Administration (FAA), may adopt these standards or apply standards that are more conservative (e.g., require greater distances between aircraft). Table 1 lists selected ICAO current and proposed minimum separation standards for oceanic airspace that rely on either Automatic Dependent Surveillance-Contract (ADS-C) or space-based Automatic Dependent Surveillance-Broadcast (ADS-B).

Table 2: Selected International Civil Aviation Organization (ICAO) Minimum Separation Standards for Oceanic Airspace[a]

Separation standard	Aircraft requirements	Other requirements	Status

Lateral distance: 23 nautical miles (NM)	• Required navigation performance[b] of 2NM (RNP 2) or 4NM (RNP 4);
	• Required communication performance[c] of 240 seconds (RCP 240);
	• Required surveillance performance[d] of 180 seconds (RSP 180);
	• Use Automatic Dependent Surveillance-Contract (ADS-C) to send reports when
	  • aircraft passes a waypoint, or
	  • aircraft deviates laterally from flight plan
		Tracks are parallel or non-intersecting	Published in 2016

Separation standard	Aircraft requirements	Other requirements	Status
Lateral distance: 19 NM	• RNP 2 or 4; • RCP 240; • Use air traffic services (ATS) surveillance (Currently space-based Automatic Dependent Surveillance-Broadcast (ADS-B) is the only ATS surveillance technology available in oceanic airspace)	Tracks are parallel, non-intersecting, or intersecting	Pending; approval expected in 2020
Lateral distance: 15 NM	• RNP 2 or 4; • RCP 240; • Use ATS surveillance (Currently space-based ADS-B is the only ATS surveillance technology available in oceanic airspace)	Tracks are parallel, non-intersecting, or intersecting and airspace meets other density or stringent deviation measures	Pending; approval expected in 2020
Longitudinal distance: 30 NM	• RNP 2 or 4; • RCP 240; • RSP 180 • Maximum ADS-C periodic reporting interval of 12 minutes	Same track or crossing tracks provided the relative angle between tracks is less than 90 degrees	Published in 2002
Longitudinal distance: 20 NM	• RNP 2 or 4; • RCP 240; • RSP 180; • Maximum ADS-C periodic reporting interval of 3.2 minutes	Same track or crossing tracks provided the relative angle between tracks is less than 90 degrees	Pending; approval expected in 2020
Longitudinal distance: 17 NM	• RNP 2 or 4; • RCP 240; • Use ATS surveillance (Currently space-based ADS-B is the only ATS surveillance technology available in oceanic airspace)	Same tracks or crossing tracks provided the relative angle between tracks is less than 90 degrees	Pending; approval expected in 2020
Longitudinal distance: 14 NM	• RNP 2 or 4; • RCP 240; • Use ATS surveillance (Currently space-based ADS-B is the only ATS surveillance technology available in oceanic airspace)	Relative angle between tracks is less than 45 degrees	Pending; approval expected in 2020

Source: GAO analysis of ICAO information. | GAO-19-532

Note: NM = nautical mile; a nautical mile is a unit of measure based on the circumference of the earth. One nautical mile equals 1.15 land measured miles. Nautical miles are used for navigating the air and sea.

[a]Oceanic airspace refers to airspace in which direct controller-pilot very high frequency (VHF) communication is not available.

[b]Required navigation performance (RNP) describes the accuracy of an aircraft's navigation performance. A smaller RNP value indicates a higher degree of navigational accuracy. For example, RNP 4 requires an aircraft to be capable of remaining within 4 nautical miles of the centerline of its route 95 percent of the time and within 8 nautical miles 99.999 percent of the time.

[c]Required communication performance (RCP) specifies the number of seconds with which there is a 99.9 percent probability that a communication message sent by an air traffic controller to a pilot will be received and the pilot's acknowledgment of the message received by air traffic control. For example, RCP 240 requires a 99.9 percent probability that this communication transaction be completed in 240 seconds or less.

[d]Required surveillance performance (RSP) specifies the number of seconds with which there is a 99 percent probability that information sent from an aircraft to air traffic control is received. For example, RSP 180 requires a 99 percent probability that this surveillance transaction be completed in less than 180 seconds.

Separation Standards Commonly Applied in U.S. Oceanic Airspace

The lateral and longitudinal separation standards commonly applied by U.S. air traffic controllers in U.S. oceanic airspace—the Anchorage Arctic, Anchorage Oceanic, New York Oceanic, and Oakland Oceanic flight regions—are shown in table 2.

Table 3: Separation Standards Commonly Applied in U.S. Oceanic Airspace

Separation standard	Aircraft requirements

Lateral distance: 30 nautical miles (NM)	• Required navigation performance of 4 NM (RNP 4)[a]
	• Future Air Navigation System (FANS) with satellite communication network, which includes
	  • Controller Pilot Data Link Communication (CPDLC)[b]
	  • Automatic Dependent Surveillance-Contract (ADS-C)[b] sending reports when
	    • aircraft passes a waypoint or
	    • aircraft deviates laterally from flight plan

Lateral distance: 50 NM	• Required navigation performance of 10 NM (RNP 10)[a]
Lateral distance: l00 NM	• None

Longitudinal distance: 30NM	• RNP 4[a]
	• FANS with satellite communication network
	  • CPDLC[b]
	  • ADS-C[b] sending periodic position reports every 10 minutes

Longitudinal distance: 50 NM	• RNP 10[a]
	• FANS with satellite communication network
	  • CPDLC[b]
	  • ADS-C[b] sending periodic position reports every 27 minutes[c]

Longitudinal distance: 10 minutes (approx. 80 NM)[d]	• High frequency voice communications (via radio operator) • Maintain flight speed as assigned by Air Traffic Control (New York oceanic flight region only)
Longitudinal distance: 15 minutes (approx. 120 NM)[d]	• None

Source: GAO analysis of FAA information. | GAO-19-532

Note: NM = nautical mile; a nautical mile is a unit of measure based on the circumference of the earth. One nautical mile equals 1.15 land measured miles. Nautical miles are used for navigating the air and sea.

[a]Required navigation performance (RNP) describes the accuracy of an aircraft's navigation performance. A smaller RNP value indicates a higher degree of navigational accuracy. For example, RNP 4 requires an aircraft to be capable of remaining within 4 nautical miles of the centerline of its route 95 percent of the time and within 8 nautical miles 99.999 percent of the time.

[b]CPDLC and ADS-C must meet Performance Based Communication and Surveillance requirements to be eligible for these separation standards. Required communication performance (RCP) specifies the number of seconds with which there is a 99.9 percent probability that a communication message

sent by an air traffic controller to a pilot will be received and the pilot's acknowledgment of the message received by air traffic control. CPDLC must meet RCP 240, which requires a 99.9 percent probability that this communication transaction be completed in 240 seconds or less. Required surveillance performance (RSP) specifies the number of seconds with which there is a 99 percent probability that information sent from an aircraft to air traffic control is received. ADS-C must meet RSP 180, which requires a 99 percent probability that this surveillance transaction be completed in less than 180 seconds.

[c]All regions have implemented 14-minute periodic reporting for ADS-C for RNP 10 aircraft to support aircraft tracking.

[d]Assumes a cruising speed of roughly 8 nautical miles per minute.

Aircraft meeting these communication, navigation, and surveillance equipment and performance requirements are eligible for the separation standards detailed above. However, the actual standards applied by U.S. air traffic controllers depend on several factors, including the number of similarly eligible aircraft and air traffic volume. For example, while an aircraft may be eligible to use the 30 nautical mile lateral separation standard, nearby aircraft may not. When aircraft with differing communication, navigation, and/or surveillance capabilities are flying near one another, air traffic controllers must apply the larger separation standard based on the aircraft with the fewest capabilities.

Air traffic controllers consider not just an aircraft's current location but also where it is going when applying separation standards. Therefore, as aircraft approach the boundaries of U.S. oceanic airspace, U.S. air traffic controllers also consider the separation standards and eligibility requirements of the neighboring flight region. Based on our interviews, U.S. air traffic controllers hand off aircraft to their foreign counterparts (and vice versa) so that aircraft enter a new flight region in conformance with that flight region's standards. For example, air traffic controllers managing aircraft in the Anchorage Oceanic flight region do not typically space aircraft heading towards Russian oceanic airspace (the Magadan Oceanic Flight Information Region) at the minimum separation—even if they are eligible. According to these air traffic controllers, any benefits that aircraft would gain from flying at the minimum separation distance in U.S. airspace would be lost when entering Russian airspace, where the separation standards are 10 minutes longitudinal (approximately 80 nautical miles). Therefore, aircraft must be spaced at least 10 minutes apart longitudinally upon entering Russian airspace.

As shown in tables 1 and 2 above, FAA uses the 30 nautical mile longitudinal standard but does not use the 23 nautical mile lateral standard. According to interviews with FAA officials and FAA documentation, FAA plans to adopt and start using the 23 nautical mile lateral standard in U.S. oceanic airspace in 2021 and the 20 nautical mile longitudinal standard in this airspace in 2022. According to FAA officials, the agency does not plan to adopt the other ICAO proposed minimum standards (i.e., 19 or 15 nautical miles lateral and 17 or 14 nautical miles longitudinal) that depend on the use of space-based ADS-B at this time.

Appendix III: Acquisition Steps Completed by the Advanced Surveillance Enhanced Procedural Separation (ASEPS) Program

The Federal Aviation Administration (FAA) Acquisition Management System (AMS) policy outlines a process for evaluating potential investments.[1] This process includes the following milestones:

1. definition of the concept and requirements of a program;
2. investment analysis readiness decision;
3. initial investment decision (business case analysis to determine the best solution);
4. final investment decision (final business case and implementation planning); and
5. solution implementation (program implementation).

FAA's corporate-level acquisition decision-making body—the Joint Resources Council (JRC)[2] —approves or disapproves at each AMS milestone. If the JRC approves the final investment decision, this commits FAA to funding the program segment and moving forward with the investment plan.

[1]FAA developed its Acquisition Management System (AMS) in response to Section 348 of Pub. L. No. 104-50, 109 Stat.436, 460, Department of Transportation and Related Agencies Appropriations Act, 1996, which exempted FAA from most federal acquisition laws.

[2]The JRC is the FAA senior investment review board. It makes corporate-level resource decisions, including authorization and funding for investment programs. The JRC may approve, disapprove, modify, or terminate an investment initiative at any AMS decision point.

From January 2014 to April 2019, FAA's Advanced Surveillance Enhanced Procedural Separation (ASEPS) program—tasked with evaluating and comparing the costs and benefits of enhanced Automatic Dependent Surveillance–Contract (ADS-C) and space-based Automatic Dependent Surveillance–Broadcast (ADS-B)—progressed through the following steps in the AMS process to prepare for a final investment decision on enhancing surveillance and enabling new minimum separation standards in U.S. oceanic airspace.

- **January 2014 (investment analysis readiness decision).** JRC approved FAA to begin further analysis of options, including enhanced ADS-C and space-based ADS-B to support the adoption of reduced separation standards in U.S. oceanic airspace. As part of this analysis, FAA took the following actions.
  - **July 2015.** JRC recommended that the ASEPS program continue evaluating the space-based ADS-B option to accommodate user (i.e., airline) preference.
  - **July 2016.** FAA tasked the NextGen Advisory Committee[3] with evaluating (1) the need and benefit of enhanced surveillance capabilities, including associated costs, funding mechanisms and funding models and (2) evaluate the business case, including insight regarding several operational factors impacting potential benefits from an investment. FAA requested input from the NextGen Advisory Committee to better understand industry's assessment of (1) the quantified benefit that industry expects the investment will deliver and (2) how much industry would be willing to pay if it was responsible for the investment. However, according to FAA officials, the report did not address the quantified benefit industry expects the investment will deliver, determine how much industry would be willing to pay if it was responsible for the investment, or conduct an overall assessment of whether the investment is cost beneficial to industry.[4] The report cited not having sufficient information, such as expected benefits and costs, to conduct an analysis of how much industry would be willing to invest.

[3]The NextGen Advisory Committee provides independent advice and recommendations to FAA and responds to specific taskings received directly from FAA.

[4]Enhanced Surveillance Task Group of the NextGen Advisory Committee, *Enhanced Surveillance Capabilities in FAA Controlled Oceanic Airspace: Operational Need and Added Benefits,* RTCA (June 2017).

- **October 2017 (initial investment decision).** ASEPS Program presented the initial business case analysis[5] comparing the two enhanced surveillance options, enhanced ADS-C and space-based ADS-B, to the JRC. Given the negative return on investing in space-based ADS-B, the JRC directed the ASEPS program to evaluate the costs and benefits of space-based ADS-B within sub-sectors of U.S. oceanic flight regions, such as Oakland flight region north and New York east.
    - **March 2018.** JRC directed the ASEPS Program to proceed with both enhanced surveillance options—enhanced ADS-C and space-based ADS-B—to a final investment decision, which was planned for September 2018.
    - **June 2018.** ASEPS Program proposed a strategic shift, which involved delaying the final investment decision on enhanced ADS-C and deferring a final investment decision on space-based ADS-B to allow additional testing on how to use space-based ADS-B in oceanic and domestic airspace. Drivers of this shift in approach included the results of the business case analysis.
- **September 2018 (strategy decision).**[6] JRC approved the ASEPS program's strategic shift.
    - The ASEPS Program asked the JRC to approve their plan to delay a final investment decision on enhanced ADS-C and to defer a final investment decision on space-based ADS-B.
    - The JRC approved the ASEPS program's proposal to merge the ASEPS enhanced ADS-C investment with a planned final investment decision on upgrades to the Advanced Technology and Oceanic Procedures (ATOP) system.
    - The JRC also approved the ASEPS program's proposal to continue studying space-based ADS-B through an operational evaluation in U.S. offshore airspace and longer-term studies concerning using space-based ADS-B for contingency operations and future use in U.S. oceanic airspace.

[5]See app. IV for more details on the costs and benefits included in the initial and final ASEPS business case analyses.

[6]A strategy decision involves the program informing the JRC of a change to an investment, seeks clarification, or approval from the JRC for a decision that is not captured in a typical AMS milestone decision.

- **April 2019 (final investment decision).** JRC approved a final investment decision on the ASEPS Program's plan to use enhanced ADS-C to enable new minimum separation standards in U.S. oceanic airspace.
    - The ATOP program management office asked the JRC to approve investments in large-scale ATOP enhancements that include system changes that will enable the implementation of new minimum separation standards (i.e., 23 nautical miles lateral and 20 nautical miles longitudinal) with the use of enhanced ADS-C.

Appendix IV: Costs and Benefits in the Advanced Surveillance Enhanced Procedural Separation (ASEPS) Business Case Analysis

As part of its acquisition process (outlined in app. III), the Federal Aviation Administration (FAA) contracted with a third-party to prepare a business case analysis for the Advanced Surveillance Enhanced Procedural Separation (ASEPS) program. This analysis estimated the costs to the agency and aircraft operators, identified safety benefits from enhanced surveillance, and identified and calculated the value of efficiency benefits from applying new minimum separation standards enabled by two technologies: enhanced Automatic Dependent Surveillance-Contract (ADS-C) and space-based Automatic Dependent Surveillance-Broadcast (ADS-B). The analysis described below was developed for FAA's initial and final investment decision on the program:[1]

- ASEPS Initial Business Case (August 2017). This business case analysis compared the costs and benefits of space-based ADS-B and enhanced ADS-C to a baseline scenario.
- ASEPS Final Business Case (August 2018). This business case analysis compared the costs and benefits of enhanced ADS-C to a baseline scenario. No final business case analysis was prepared for space-based ADS-B since FAA deferred a final investment decision on the use of space-based ADS-B.

This appendix discusses the costs and benefits that were included in these business case analyses based on our review of FAA's business case documentation and interviews with FAA officials.

[1]We did not include the estimated dollar value of the costs and benefits included in FAA's initial or final business case analyses because FAA officials determined these figures were procurement sensitive.

Description of Baseline, Enhanced ADS-C, and Space-based ADS-B Scenarios

In the initial business case, a baseline scenario and two alternative scenarios were used to evaluate the costs and benefits of using enhanced ADS-C and space-based ADS-B as compared to not using these enhanced surveillance options:

- baseline with no change in current minimum separation standards of 30 nautical miles lateral and 30 nautical miles longitudinal,[2]
- use enhanced ADS-C with minimum separation standards of 23 nautical miles lateral and 23 nautical miles longitudinal, and
- use space-based ADS-B with minimum separation standards of 15 nautical miles lateral and 15 nautical miles longitudinal.[3]

In the final business case analysis, only a baseline scenario and the enhanced ADS-C scenario were included.

[2]Other air navigation service providers have also analyzed the costs and benefits of using one or both of these technologies. For example, representatives of the air navigation service providers in the United Kingdom and Canada told us that in their analyses the safety and efficiency benefits of space-based ADS-B resulted in a positive business case for using it .The Portuguese air navigation service provider is currently analyzing the costs and benefits of these technologies by weighing the value of fuel savings to airspace users against the cost of space-based ADS-B. However, according to FAA officials, other air navigation service providers have generally conducted benefits analysis using a different baseline. For example, an air navigation service provider with a baseline scenario using minimum separation standards of 50 nautical miles lateral and longitudinal would see greater benefits when moving to the minimum separation standards enabled by space-based ADS-B than if their baseline scenario used 30 nautical miles lateral and longitudinal.

[3]FAA's initial and final business cases assume enhanced ADS-C will enable new minimum separation standards of 23 nautical miles lateral and 23 nautical miles longitudinal. These analyses also assume that space-based ADS-B will enable new minimum separation standards of 15 nautical miles lateral and 15 nautical miles longitudinal. These standards differ than ICAO's proposed new minimum separation standards (23 nautical miles lateral and 20 nautical miles longitudinal for enhanced ADS-C and 19 nautical miles lateral and 17 nautical miles longitudinal for space-based ADS-B, see app. II for more details). According to FAA officials, this difference would not change the business case findings. Indeed, the difference between the standards used in FAA's business case analysis and the actual standards may underrepresent the benefits of enhanced ADS-C and over represent the benefits of space-based ADS-B.

In the business case analysis, costs and benefits were modelled between 2020 and 2040 in the Atlantic and Pacific Oceans. To model these scenarios, researchers used projections on flight demand and aircraft equipage with the technology required to use these enhanced surveillance services: Future Air Navigation System (FANS)[4] or ADS-B and FANS.

Costs

In order to use enhanced ADS-C and space-based ADS-B to enable new minimum separation standards, FAA and airspace users will need to make certain investments. Based on our review of FAA's business case documentation, we found that certain costs were factored into the business case analysis, including:

- upgrades to the Advanced Technologies and Oceanic Procedures (ATOP) system[5]
- additional ADS-C message traffic, and
- subscription fee for space-based ADS-B service

The final business case analysis focused on enhanced ADS-C and included only those costs to FAA and users related to use of this service.

The business case analysis focused on the costs of these enhanced surveillance services and did not include the cost of equipping aircraft with FANS and/or ADS-B equipment, which are required to use these enhanced surveillance technologies. According to FAA officials, these costs were not included because aircraft operators are equipping their aircraft for other reasons. Specifically, FAA regulations requiring ADS-B equipment for aircraft flying through U.S. domestic airspace by 2020 means most aircraft flying in U.S. oceanic airspace will be ADS-B

[4]FANS includes a communication system—Controller Pilot Data Link Communications (CPDLC)—and a surveillance system—Automatic Dependent Surveillance-Contract (ADS-C).

[5]ATOP is the computer system FAA air traffic controllers use to help them manage oceanic airspace. ATOP provides oceanic air traffic controllers with several automated decision support tools to, among other things, assist in maintaining aircraft separation, coordinate with air traffic controllers in other flight regions, and facilitate controller-pilot communication.

equipped.[6] In addition, mandates from other air navigation service providers requiring FANS will compel most aircraft crossing into non-U.S. oceanic airspace to equip with FANS.[7]

Costs to FAA

The business case considered the costs FAA would incur using the data from these enhanced surveillance technologies, including upgrades to ATOP software.

Costs to Airspace Users

The business case analysis also considered the costs airspace users would face in using these enhanced surveillance technologies. In the business case analysis, FAA assumed that aircraft operators would continue to pay for ADS-C services. Since enhanced ADS-C would involve more messages per flight hour than currently sent via ADS-C, FAA estimated that aircraft operators would see an increase in messaging costs per flight hour, according to our review of FAA documentation. FAA also made assumptions about how much a subscription fee for space-based ADS-B will cost. As a new service that FAA has not yet contracted for, the actual cost of space-based ADS-B subscription fees are not known. However, initial estimates of the cost per flight hour for space-based ADS-B are much greater than the estimated cost per flight hour of additional ADS-C messages, according to FAA.

Benefits

FAA's business case analysis considered safety benefits and efficiency benefits. As detailed in the analysis, the size of these benefits depends on the participation of aircraft in each enhanced surveillance service (i.e., enhanced ADS-C and space-based ADS-B). The benefits presented in the business case represent the maximum benefit pool. Specifically, the

[6]14 C.F.R. §§ 91.225, and 91.227. Effective January 1, 2020, aircraft operating in airspace defined in 91.225 are required to have an Automatic Dependent Surveillance – Broadcast (ADS-B) system that includes a certified position source capable of meeting requirements defined in 91.227.

[7]For example, the North Atlantic Data Link Mandate requires that by January 30, 2020, all aircraft operating at or above Flight Level 290 in the North Atlantic Region must be equipped with FANS or equivalent systems.

analysis assumes that all properly equipped aircraft will use space-based ADS-B or enhanced ADS-C services.

Safety Benefits

The business case analysis discussed safety benefits offered by improved surveillance, such as increased air traffic controller situational awareness and improved detection and resolution of aircraft on conflicting flight paths. According to oceanic air traffic controllers we interviewed at the three air route traffic control centers responsible for U.S. oceanic airspace, enhancing surveillance capabilities offers safety benefits, such as improved situational awareness and search and rescue capabilities. Enhanced ADS-C and space-based ADS-B both offer these safety benefits. However, space-based ADS-B also provides information to air traffic controllers to reduce the risk of a vertical collision between aircraft.[8] This safety benefit was monetized by FAA.

Efficiency Benefits

Enhanced surveillance can enable a reduction in the minimum required distance applied between aircraft, with potential efficiency benefits for airspace users. The three efficiency benefits included in FAA's business case analysis that were monetized are:

- **Improved accommodation of altitude requests.** According to FAA's analysis, a primary benefit of reduced separation standards is that aircraft will be more likely to fly at a fuel-efficient altitude. In oceanic airspace, aircraft must make a request to air traffic control to change their altitude.[9] Despite the immensity of oceanic airspace, there is competition for the most fuel-efficient altitudes at certain times of day. For example, according to oceanic air traffic controllers in Oakland, the majority of the air traffic they handle is flights between Hawaii and the U.S. west coast, with most aircraft departing at the same time. Air

[8]The reduced risk of vertical collision is a safety benefit unique to space-based ADS-B. ADS-B messages contain the selected flight level, which is the flight level a pilot enters into the aircraft's control panel. An air traffic controller can compare the selected flight level to the cleared flight level (the flight level at which the controller directed the pilot to fly). If the pilot made a mistake inputting the flight level into the control panel, a controller will know and can correct the mistake—reducing the risk that the aircraft will collide with another aircraft.

[9]FAA, *Advisory Circular 91-70B, Oceanic and Remote Continental Airspace Operations,* (Washington, D.C.: Oct. 4, 2016).

traffic controllers we spoke with agreed that with enhanced surveillance and reduced separation standards, they should be able to grant more altitude requests and allow more aircraft to fly at optimal altitudes.

- **Reduced need for aircraft to carry extra fuel.** According to FAA's analysis, aircraft operators typically carry more fuel on an aircraft than needed to fly their planned route. Aircraft carry extra fuel to hedge against the possibility that its actual flight path will be less fuel-efficient than its planned flight path. The cost of carrying extra fuel (i.e., the cost to carry) comes from the added weight of carrying extra fuel, weight that causes an aircraft to use more fuel and that reduces an aircraft's ability to carry revenue-generating cargo. This benefit flows from the improved accommodation of altitude requests, discussed above.
- **More efficient arrivals and departures at Pacific island airports.** According to FAA's analysis, some Pacific island airports do not have radar surveillance and require U.S. oceanic air traffic controllers in the Oakland air route traffic control center to manage aircraft arrivals and departures.[10] As a result, oceanic separation standards are applied as aircraft arrive and depart these islands' airports. FAA's analysis shows that reducing oceanic separation minimums will allow air traffic controllers to allow more frequent arrivals and departures from these airports. According to this analysis, the benefit of more frequent arrivals and departures is measured in terms of the costs to aircraft operators (an aircraft's direct operating costs) and the cost to passengers (a passenger's value of time).

FAA's business case analysis also includes efficiency benefits of reduced separation that were not monetized, including emissions savings and improved air traffic control accommodation of aircraft requests for descents, routing changes, and speed changes. FAA policy does not currently allow programs to value carbon dioxide emissions avoided for investment decisions. Another efficiency benefit of reduced separation—giving air traffic controllers more flexibility to grant deviations from planned flight paths due to disruptive weather—was quantified and monetized, but not factored into the benefit calculation.

[10]FAA's analysis included airports without radar surveillance in the following Pacific islands: Marshall Islands, Republic of Kiribati, U.S. Midway Island, Federated States of Micronesia, Republic of Palau, and U.S. Wake Island.

Appendix V: Federal Aviation Administration's 18 Critical Milestones to Implement a New Separation Standard

To implement new separation standards in U.S. oceanic airspace, the Federal Aviation Administration (FAA) has a set of 18 critical milestones that it follows:

1. Determine the operational need.
2. Evaluate the benefits.
3. Establish an operational concept.
4. Assess the impact on air traffic control.
5. Conduct a safety assessment and record it with the appropriate safety risk management documentation.
6. Determine requirements.
7. Conduct a feasibility and economic analysis.
8. Establish requirements for aircraft and operator approval.
9. Conduct rulemaking.
10. Coordinate with industry and international participants.
11. Coordinate with air traffic control representatives and pilot groups.
12. Complete regional documentation.
13. Acquire approval for aircraft and operators.
14. Develop pilot and air traffic control procedures.
15. Design pilot and air traffic control training materials.
16. Confirm that the system works.
17. Employ the separation standard.
18. Monitor the performance of the system in accordance with safety risk management practices.

Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact

Heather Krause at (202) 512-2834 or krauseh@gao.gov

Staff Acknowledgments

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