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Report to Congressional Requesters

August 2017

AIR TRAFFIC CONTROL MODERNIZATION

Progress and Challenges in Implementing NextGen

Accessible Version

GAO-17-450

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GAO Highlights

Highlights of GAO-17-450, a report to congressional requesters

Why GAO Did This Study

FAA is leading the implementation of NextGen, which is designed to transition the nation's ground-based air traffic control system to one that uses satellite navigation, automated position reporting, and digital communications. Planning for NextGen began in 2003 and in 2007 the effort was estimated to cost between $29 and $42 billion by 2025. NextGen is intended to increase air transportation system capacity, enhance airspace safety, reduce delays, save fuel, and reduce adverse environmental effects from aviation.

Given the cost, complexity, and length of the project, GAO was asked to review FAA's NextGen implementation efforts. This report examines: 1) how FAA has implemented NextGen and addressed implementation challenges; and 2) the challenges, if any, that remain for implementing NextGen, and FAA's actions to mitigate those challenges.

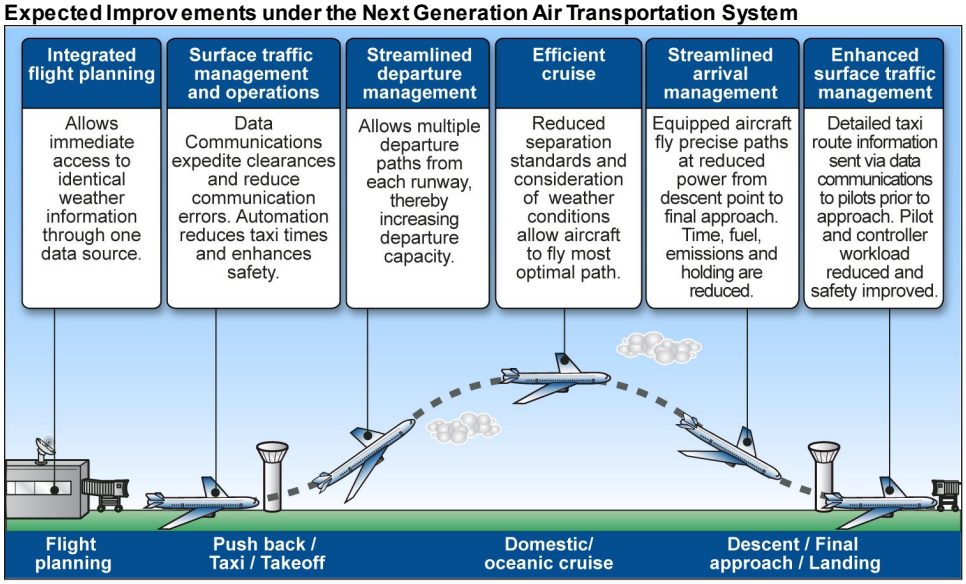
GAO reviewed FAA documents, advisory group reports, and NextGen-related recommendations made to FAA by GAO and others. GAO interviewed a non-generalizable sample of 34 U.S. aviation industry stakeholders, including airlines, airports, aviation experts and research organizations, among others, to obtain their views on NextGen challenges and FAA's efforts to address them. Stakeholders were selected based on GAO's knowledge of the aviation industry and includes those that have made NextGen-related recommendations to FAA, among other things. GAO also interviewed FAA officials regarding NextGen implementation and stakeholders' views.

View GAO-17-450. For more information, contact Gerald Dillingham, Ph.D., at (202) 512-2834 or dillinghamg@gao.gov.

What GAO Found

The Federal Aviation Administration (FAA) is implementing the Next Generation Air Transportation System (NextGen) incrementally and has taken actions to address challenges to implementation. NextGen has enhanced surface traffic operations at 39 of the 40 busiest airports in the United States by providing electronic communications to clear planes for departure, technology that can expedite clearances and reduce errors. FAA has taken steps to address challenges such as limited stakeholder inclusion that affected early implementation of NextGen. For example, FAA established groups of industry stakeholders and government officials, who worked together to develop implementation priorities. By 2025, FAA plans to deploy improvements in all NextGen areas—communications, navigation, surveillance, automation, and weather. While specific NextGen initiatives and programs have changed over time, FAA's 2016 cost estimates for implementing NextGen through 2030 for 1) FAA and 2) industry—$20.6 and $15.1 billion, respectively—are both within range of 2007 cost estimates.

Expected Improvements under the Next Generation Air Transportation System



Source: GAO analysis of FAA information. | GAO-17-450

FAA's challenges as it continues to implement NextGen include uncertainties regarding future funding; whether aircraft owners equip their aircraft to use NextGen improvements; potential air traffic control restructuring; FAA's leadership stability; and cybersecurity issues. FAA is taking actions to address challenges within its control by, for example, prioritizing NextGen improvements and segmenting them into smaller pieces that each require less funding. While it is not possible to eliminate all uncertainties, FAA has adopted an enterprise risk management approach to help it identify and mitigate current and future risks that could affect NextGen implementation. Moreover, FAA has implemented most of GAO's related recommendations.

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Abbreviations

ADS-B Automatic Dependent Surveillance-Broadcast

AIMM	Aeronautical Information Management Modernization
ATC	air traffic control
ATN	Aeronautical Telecommunications Network
ATO	Air Traffic Organization
AVS	Office of Aviation Safety
CATM-T	Collaborative Air Traffic Management-Technologies
CSS-Wx	Common Support Services-Weather
CIO	Chief Information Officer
DAC	Drone Advisory Committee
Data Comm	Data Communications
DOT	Department of Transportation
DOT OIG	Department of Transportation's Office of Inspector General
FAA	Federal Aviation Administration
F&E	facilities and equipment
ERAM	En Route Automation Modernization
ERM	Enterprise Risk Management
GPS	Global Positioning System
JPDO	Joint Planning and Development Organization
NAC	NextGen Advisory Committee
NAS	National Airspace System
NextGen	Next Generation Air Transportation System
NPS	NextGen Performance Snapshots
NVS	National Airspace System Voice System
NWP	NextGen Weather Processor
OIG	Office of Inspector General
OMB	Office of Management and Budget
PBN	Performance-Based Navigation
RE&D	research, engineering and development
RTCA	formerly known as the Radio Technical Commission for Aeronautics
SOA	Service Oriented Architecture
SWIM	System Wide Information Management
TAMR	Terminal Automation Modernization and Replacement
TBFM	Time Based Flow Management
TFDM	Terminal Flight Data Manager
TMA	Traffic Management Advisor
UAS	unmanned aircraft systems
Wake Recat	Wake Turbulence Re-Categorization

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August 31, 2017

The Honorable Bill Shuster
Chairman
The Honorable Peter DeFazio
Ranking Member
Committee on Transportation and Infrastructure
House of Representatives

The Honorable Frank LoBiondo
Chairman
The Honorable Rick Larsen
Ranking Member
Subcommittee on Aviation
Committee on Transportation and Infrastructure
House of Representatives

The U.S. National Airspace System (NAS) handles nearly 70,000 flights a day and is generally considered the safest, busiest and most complex airspace system in the world.[1] Key aviation stakeholders—the Federal Aviation Administration (FAA), airlines, airports, general aviation, business aviation, aircraft manufacturers, and aviation professionals—work together to ensure these results. As part of this effort, FAA is leading the development of the Next Generation Air Transportation System (NextGen), a complex, long-term initiative that will transition the current ground-based radar air-traffic control system to a system based on satellite navigation, automated position reporting, and digital communications. NextGen is intended to, among other things, increase air transportation system capacity, enhance airspace safety, reduce delays experienced by airlines and passengers, save fuel, and reduce adverse environmental impacts from aviation. Full implementation of NextGen requires investment by the federal government through FAA, as well as by airlines in new technologies and the development of new policies and procedures.

[1]The National Airspace System is a shared network of U.S. airspace; air navigation facilities, equipment, and services; airports or landing areas; aeronautical charts, information, and services; rules, regulations, and procedures; technical information; and manpower and material.

In December 2003, Congress passed the Vision 100—Century of Aviation Reauthorization Act, which created the Joint Planning and Development Organization (JPDO) within FAA to plan for and coordinate an interagency effort to transition to NextGen by 2025.[2] However, FAA has been largely responsible for implementing the policies and systems necessary for NextGen to become operational. In 2014, with NextGen implementation underway, Congress ended funding for JPDO, and FAA's Interagency Planning Office assumed lead responsibilities for coordinating FAA's NextGen implementation with other agencies.[3]

We have monitored and reported on NextGen since its inception.[4] After more than a decade of planning and implementation, you asked us to review the status of FAA's NextGen implementation efforts. This report examines: (1) how FAA has implemented NextGen and addressed implementation challenges; and (2) the challenges, if any, that remain for implementing NextGen, and FAA's actions to mitigate those challenges.

To address these objectives, we reviewed FAA planning documents for NextGen and FAA reports and briefings related to ongoing NextGen efforts. We also assessed current cost estimates for implementing NextGen through 2030 and compared them to 2007 estimates from JPDO. We reviewed reports and NextGen-related recommendations issued by GAO, the Department of Transportation's (DOT) Office of Inspector General (DOT OIG), and NextGen advisory groups; and assessed FAA's efforts to address these recommendations. We interviewed FAA officials with a role in implementing NextGen, including

[2]FAA's partner agencies in the JPDO included the Department of Transportation, the Department of Defense, the Department of Homeland Security, the Department of Commerce, the National Aeronautics and Space Administration, and the Office of Science and Technology Policy in the Executive Office of the President. Vision 100—Century of Aviation Reauthorization Act, Pub. L. No. 108-176, §§ 709-710, 117 Stat. 2490, 2582 (2003).

[3]The Interagency Planning Office is located within the Office of NextGen and coordinates with agencies such as the Departments of Defense and Homeland Security.

[4]See, for example, GAO, *National Airspace System: Transformation Will Require Cultural Change, Balanced Funding Priorities, and Use of All Available Management Tools*, GAO-06-154 (Washington, D.C.: Oct. 14, 2005); GAO, *NextGen Air Transportation System: FAA's Metrics Can Be Used to Report on Status of Individual Programs, but Not of Overall NextGen Implementation or Outcomes*, GAO-10-629 (Washington, D.C.: July 27, 2010); GAO, *Next Generation Air Transportation System: Improved Risk Analysis Could Strengthen Global Interoperability Efforts*, GAO-15-608 (Washington, D.C.: July 29, 2015).

officials within the NextGen Office and its Interagency Planning Office, the Office of Aviation Safety (AVS), and the Air Traffic Organization (ATO). To obtain a diverse set of views, we also interviewed 34 stakeholders using open-ended questions to obtain their perspectives on efforts FAA has made to address challenges that have affected NextGen implementation. These 34 stakeholders consisted of a non-probability sample of aviation experts and officials from airlines, airports, former FAA officials, research and development organizations, general aviation associations, labor unions and professional associations, and manufacturers and service providers. We created an initial list of stakeholders using internal knowledge of the aviation industry. We further developed the list of stakeholders by reviewing NextGen-related literature and identifying industry stakeholders that have made NextGen-related recommendations to FAA. To determine the common themes that we are reporting on, we conducted a content analysis of the interviewees' responses. The results of our interviews are not generalizable to all industry stakeholders. For more information on our scope and methodology, including a listing of FAA divisions and industry stakeholders we interviewed, see appendix I.

We conducted this performance audit from November 2015 to August 2017 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

FAA's Early Modernization Efforts for Air Traffic Control

FAA has pursued several different modernization efforts for air traffic control (ATC) since FAA's creation by the Federal Aviation Act of 1958.[5] These efforts to upgrade the air-traffic control system included the installation of a semi-automated air-traffic control system beginning in the

[5]Federal Aviation Act of 1958, Pub. L. No. 85-726, § 301, 72 Stat. 731, 744 (1958). In 1966, the previously independent Federal Aviation Agency that the Act created was renamed the Federal Aviation Administration and made part of the new Department of Transportation. Pub. L. No. 89-670, § 3(e)(1), 80 Stat. 931, 932 (1966).

mid-1960s and an air traffic control modernization program beginning in 1981. The 1981 modernization program was intended to replace and upgrade the equipment and facilities of the NAS to meet an expected increase in traffic volume, enhance the margin of air safety, and increase the efficiency of the air-traffic control system. The centerpiece of the program was the Advanced Automation System, which would replace computer hardware and software and controller work stations at tower, terminal, and en-route facilities.

FAA restructured the automation program in 1994 after the estimated cost to deploy it had tripled, capabilities were shown to be significantly less than promised, and delays were expected to run nearly a decade.[6] In 1995, we placed FAA's air traffic control modernization efforts on our watch list of high-risk federal programs due to the cost, complexity, criticality to FAA's mission, and problematic history.[7] By 2003, the estimated cost of FAA's air-traffic control modernization efforts had grown from $12 billion to $51 billion.

NextGen

In the early 2000s, the U.S airspace system was experiencing significant congestion and delays, with about one in every four flights delayed. Additionally, forecasts called for a possible tripling of air traffic by 2025, which raised concerns about the air-traffic control system's ability to handle demand. In December 2003, Congress passed the Vision 100—Century of Aviation Reauthorization Act, which created the JPDO within FAA to plan for and coordinate a transition to NextGen by 2025.[8] Congress's goals for NextGen were to improve the level of safety, security, efficiency, quality, and affordability of the NAS and aviation services; take advantage of data from emerging technologies and integrate data streams from multiple sources; and accommodate and

[6]This restructuring included cancelling segments of the initial automation program, scaling back others, and ordering the development of less costly alternatives. Three of five segments of the Advanced Automation System were cancelled, one segment was scaled back, and another segment was unaffected.

[7]GAO removed FAA's air traffic control modernization efforts from the high-risk list in 2009 because of its progress in addressing most of the root causes of its past problems and its commitment to sustaining progress in the future. GAO, *High Risk Series: An Update,* GAO-09-271 (Washington, D.C.: January 2009).

[8]Vision 100—Century of Aviation Reauthorization Act, Pub. L. No. 108-176, §§ 709-710, 117 Stat. 2490, 2582 (2003).

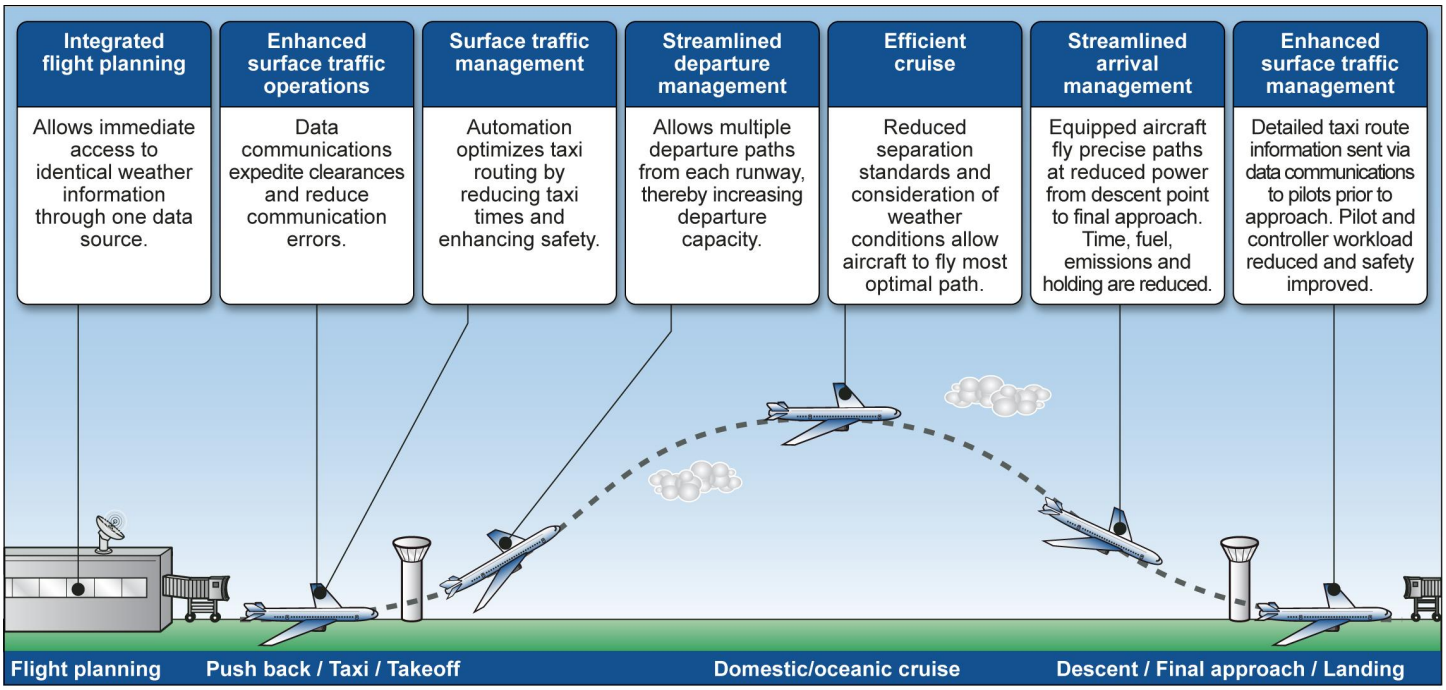
encourage substantial growth in domestic and international transportation, among other things. Congress assigned the JPDO the responsibility to develop an integrated plan for NextGen and facilitate collaboration between FAA and other federal agencies on NextGen efforts. Since passage of the Vision 100 Act, NextGen has evolved from a high-level vision developed by the JPDO to detailed plans currently being implemented by FAA.[9] See appendix II for more detail on FAA's planning and implementation documents for NextGen.

NextGen is a system of systems designed to improve operations in all phases of a flight, through the replacement of the legacy radar-based air traffic control system with a satellite-based system that includes digital communications, among other improvements. NextGen includes a variety of programs that deliver specific improvements to the NAS. See figure 1 below for some of the improvements to the phases of flight that NextGen is expected to deliver. For example, under enhanced-surface-traffic operations, a service provided by FAA's Data Communications program allows an air traffic controller to send flight-departure clearance instructions to aircraft electronically, which can expedite clearances and reduce communication errors. Under an improvement to streamline arrival management, performance-based navigation allows aircraft equipped with appropriate technology to fly precise paths at reduced power, which saves time, conserves fuel, and reduces exhaust emissions. In addition, FAA is deploying some programs that are necessary to implement NextGen programs. For example, the En Route Automation Modernization (ERAM) program replaced the computer system used by air traffic controllers at en route centers, a step that was necessary to deploy some NextGen programs.[10]

[9]The Consolidated Appropriations Act of 2014 did not include funding for the JPDO, resulting in its closure. Pub. L. No. 113-76, 128 Stat. 5 (2014). FAA has created an Interagency Planning Office within FAA to replace certain functions of the JPDO and coordinate federal investment in NextGen across agencies.

[10]En route centers are air traffic control facilities responsible for guiding aircraft as they travel between airports.

Figure 1: Improvements to Phases of Flight Expected under the Next Generation Air Transportation System



Source: GAO analysis of FAA information. | GAO-17-450

FAA Is Implementing NextGen Incrementally and Has Taken Various Actions to Address Challenges

FAA is implementing NextGen incrementally through six NextGen-related areas—communications, automation, navigation, surveillance, weather, and foundational programs. FAA has faced challenges in including stakeholders and in measuring and reporting on NextGen progress. In response, FAA has encouraged the formation of groups of stakeholders to advise it on implementing NextGen and measuring its progress, and has worked to incorporate industry preferences into its implementation of NextGen. For example, FAA is deploying new navigation procedures in "metroplexes"— geographic areas covering several airports that serve major metropolitan areas—following a recommendation from a government and industry task force. FAA has also developed a website that reports on outcome-based performance metrics for NextGen. FAA plans to implement the concepts that will transform the NAS to a NextGen

system by 2025, and current total cost estimates for NextGen are within the JPDO's 2007 estimates.

Strategy for Implementing NextGen

In the late 1990s, building on lessons learned from previous air traffic control modernization efforts and recommendations from stakeholders, FAA shifted its strategy for air traffic control modernization. In contrast to previous modernization efforts, in which FAA sought to build highly complex software-intensive systems all at once, FAA adopted a phased approach to modernization that allowed FAA to make mid-course corrections and avoid costly late-stage changes. JPDO later adopted this approach for developing and refining its enterprise architecture—a technical description of the NextGen system that was designed to provide a common tool for planning the complex, interrelated systems that would make up NextGen. According to FAA officials we interviewed, the development and implementation of NextGen is an iterative and evolutionary process. However, some stakeholders told us that FAA had originally described NextGen as a transformative initiative. A report from a 2015 National Academy of Sciences study commented that NextGen meant different things to different people, from a wide-ranging transformational vision to a much more concrete set of phased incremental changes to various parts of the NAS, and recommended resetting expectations. The study committee concluded that NextGen today is primarily an incremental modernization effort. The report also noted that given the continuing rapid pace of technological evolution and ongoing changes in what is demanded of the NAS, the NextGen effort is properly seen as an ongoing process, punctuated by particular efforts focused on particular capabilities.[11] According to FAA officials, NextGen can be both incremental and result in a transformation.

FAA has begun developing and deploying elements of many NextGen communications, automation, navigation, surveillance, and weather programs, as well as foundational programs on which NextGen improvements depend. A short overview of these six NextGen-related program areas can be found below. See appendix III for further information about select NextGen programs.

[11]National Research Council, *A Review of the Next Generation Air Transportation System: Implications and Importance of System Architecture* (Washington, DC: 2015).

- Foundational programs to provide the infrastructure necessary to deploy NextGen programs. For example, the Terminal Automation Modernization and Replacement (TAMR) program includes updates to air traffic control systems to help controllers manage air traffic.
- Communications programs to enhance communication and information sharing in the NAS. This area includes programs such as Data Communications, which will supplement the voice communications currently used to relay information between air traffic controllers and aircraft with pre-scripted email-like messages.
- Navigation programs that use more efficient routes and procedures to save fuel, reduce flight times, increase traffic flow and capacity, and reduce exhaust emissions. This area includes programs such as Performance-Based Navigation (PBN), which provides new, more efficient aircraft flight routes and procedures that primarily use satellite-based navigation.
- Surveillance programs to provide more precise tracking of aircraft, vehicles, and other objects to air traffic controllers and pilots. This area includes programs such as Automatic Dependent Surveillance-Broadcast (ADS-B), which uses Global Positioning System (GPS) satellites to determine an aircraft's location, speed, and other data.
- Automation programs to enhance air traffic control efficiency, reduce costs, and provide traffic flow management solutions. This area includes programs such as Time Based Flow Management, which is designed to optimize the flow of aircraft as they arrive in or depart from congested airspace and airports.
- Weather programs to manage and disseminate weather information, help identify safety hazards, and provide support for strategic traffic flow management.[12] This area includes programs such as Common Support Services-Weather, which will enable access to standardized weather information.

Some NextGen improvements have already been deployed. For example, Data Communications departure clearance services have been deployed at 55 airports—all of the locations for the first phase of the Data Communications program, including 39 of the 40 busiest commercial

[12]Strategic traffic flow management (as opposed to tactical traffic flow management) refers to longer-term, 2-8 hour traffic management planning efforts at a larger scale, perhaps regional or national rather than local.

airports in the United States.[13] FAA has segmented the implementation of some of its NextGen programs into time frames during which FAA will implement certain portions of the programs. By segmenting implementation, FAA divides each program into defined parts that require less funding than the entire program.

In many cases, achieving the desired NextGen outcomes depends on the successful implementation of multiple programs or capabilities. For example, more efficient air traffic control routes may provide limited benefits if air traffic controllers do not have access to tools to better manage airborne traffic. To help manage the implementation of NextGen improvements across programs, FAA has organized the operational improvements—specific operational changes to the NAS, such as the implementation of improved air traffic control procedures—into portfolios. This portfolio-based approach views NextGen as an integrated effort rather than a series of independent programs. See table 1 below for a list and description of FAA's 11 implementation portfolios.

Table 1: Federal Aviation Administration (FAA)'s Portfolios of Next Generation Air Transportation System (NextGen) Operational Improvements

Portfolio	Description
Improved Surface Operations	Seeks to improve safety, efficiency, and flexibility on the airport surface—on the ground at airports—by implementing new traffic management capabilities for pilots and controllers using shared surface movement data.
Improved Approaches and Low-Visibility Operations	Includes capabilities designed to increase airport access and flexibility through procedural changes, improved aircraft capabilities, and improved precision approach guidance—navigation guidance given to pilots to guide an aircraft on its descent to a runway.
Improved Multiple Runway Operations	Seeks to improve access to closely spaced parallel runways to enable more arrival and departure operations.
Performance-Based Navigation	Uses navigation technologies to improve access and flexibility in the National Airspace System (NAS) and provide more efficient aircraft routes.

[13]We defined the "busiest airports" as those with the most passengers boarding at each airport in 2015.

Portfolio	Description
Time-Based Flow Management	Enhances NAS efficiency by using the capabilities of the Traffic Management Advisor decision support tool, which assigns times when aircraft destined for the same airport should cross certain points in order to reach the destination airport at a specific time and in an efficient order. Uses time instead of distance to help controllers sequence aircraft.
Collaborative Air Traffic Management	Coordinates decision making by flight planners and FAA traffic managers to improve NAS efficiency, provide greater flexibility to flight planners, and make the best use of available airspace and airport capacity.
Separation Management	Provides air traffic controllers with tools and procedures to separate aircraft. Safely reducing separation between aircraft through the capabilities in this portfolio may improve capacity, efficiency, and safety in the NAS.
On-Demand NAS Information	Provides flight planners, air traffic controllers, traffic managers, and flight crews with consistent and complete information related to changes in various areas of the NAS, such as temporary flight restrictions, equipment outages, and runway closures.
Environment and Energy	Seeks to mitigate air quality, climate, energy, noise, and water quality concerns from aviation through improved scientific knowledge and integrated modeling; air traffic modernization and operational improvements; new aircraft technology; sustainable alternative aviation fuels; and policies, environmental standards, and market-based measures.
System Safety Management	Uses data acquisition, storage, analysis, and modeling capabilities being developed to ensure that new capabilities either improve or maintain current safety levels while simultaneously improving capacity and efficiency in the NAS.
NAS Infrastructure	Provides research, development, and analysis of capabilities that depend on and affect activities in more than one NextGen portfolio.

Source: GAO review of GAO and Federal Aviation Administration documents. | GAO-17-450

Limited Stakeholder Inclusion and Communications Affected Early Implementation, But FAA Has Taken Steps to Address These Challenges

Evolution of Stakeholder Inclusion

In 2008, many of the aviation stakeholders we interviewed told us that while they felt they were provided the opportunity to participate in NextGen's planning, many were not satisfied with the impact or outcome of their participation. Some of these stakeholders expressed concern that

their input was not included in the development of planning documents and other products, and that issues were not addressed or incorporated in NextGen plans.[14] This participation is critical to NextGen's implementation because NextGen depends heavily on airlines' and other stakeholders' investments in NextGen technology and training.

The need for stakeholder buy-in and investment led FAA in 2009 to request RTCA to form a task force of government and industry stakeholders.[15] This task force —called the NextGen Mid-Term Implementation Task Force—was asked to recommend NextGen improvements that could be implemented with existing technologies in the "midterm," which was defined as lasting through 2018. In 2009, this task force issued its recommendations to FAA; they prioritized operational capabilities in six areas: *surface, runway access, metroplex, cruise, access to the NAS,* and *cross-cutting*—recommendations that cut across the previous five areas (see table 2).[16] FAA accepted the Task Force recommendations and incorporated them into its annual NextGen implementation plans.

Table 2: NextGen Mid-Term Implementation Task Force Recommendation Areas

Recommendation Area	Description
Surface	Improving surface traffic management—the management of traffic on the ground at airports—to reduce delays and enhance safety, efficiency, and situational awareness through capture and dissemination of surface operations data to pilots, controllers, user operations centers, and other destinations.
Runway Access	Increasing runway access, especially in low visibility, to converging, intersecting, and closely-spaced parallel runways by leveraging potential capacity gains from accurate and predictable flight paths, as well as enhanced surveillance methods.

[14]GAO, *Next Generation Air Transportation System: Status of Systems Acquisition and the Transition to the Next Generation Air Transportation System*, GAO-08-1078 (Washington, D.C.: September 11, 2008).

[15]RTCA (formerly called the Radio Technical Commission for Aeronautics) is a public-private partnership that provides a forum for developing consensus among competing interests on aviation modernization issues, including providing industry recommendations for FAA.

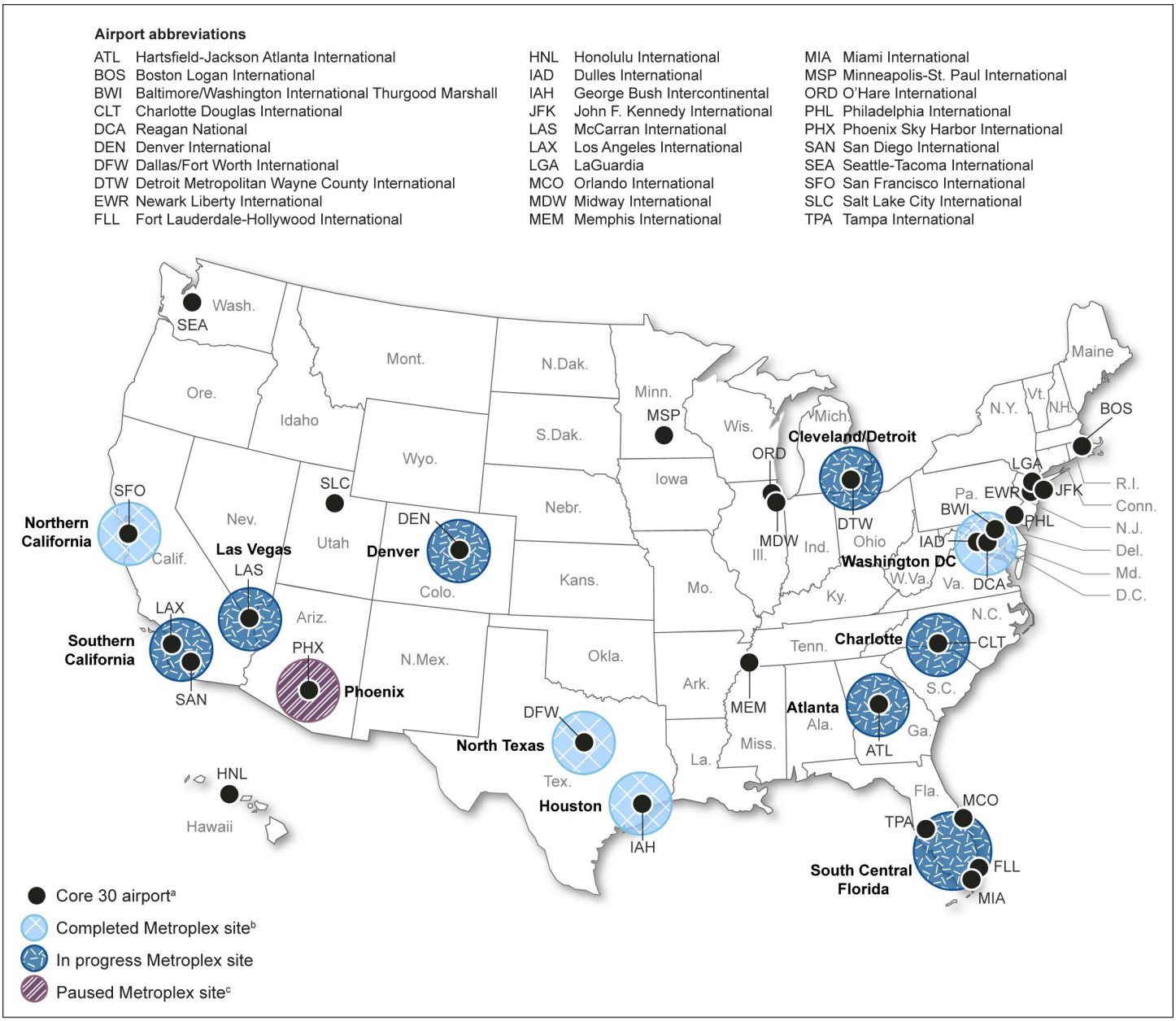
[16]*Surface* refers to operations on the ground at airports. Cruise operations occur between the climb and descent phases of flight. A *metroplex* is a geographic area covering several airports that serve major metropolitan areas.

Recommendation Area	Description
Metroplex	Relieving congestion and delays at major metropolitan areas' airports, inefficiencies at satellite airports, and surrounding airspace by instituting FAA and industry teams that focus on quality of implementation at each location and minimizing conflicts between the operations of adjacent airports.
Cruise	Improving efficiency of cruise operations—operations that occur between the climb and descent phases of flight—by increasing the ability to disseminate real-time airspace status and schedules; improving flow management to better utilize time-based metering—delivering aircraft to a specific place at a specific time—and flight operator capabilities; and implementing data communications between air traffic control systems and aircraft to more effectively manage traffic and exchange routing and clearance information.
Access to the National Airspace System	Improving access to and services provided at airports other than the Operational Evolution Partnership airports—the 35 U.S. airports with the most significant commercial activity—and to low altitude, non-radar airspace by implementing more precision-based approaches and departures, along with the expansion of surveillance services to areas not currently under radar surveillance.
Cross-Cutting	Recommendations that cut across the previous five areas, including using data communications to enable more efficient use of capacity in the National Airspace System, increasing the ability to adapt to changing conditions through improved dissemination of reroutes around weather and congestion, creating a system for managing air traffic that leverages new technologies and collaboration with the users, and implementing integrated solutions to traffic flow problems.

Source: GAO analysis of GAO, RTCA, and FAA documents. | GAO-17-450

In response to the task force recommendations, FAA has focused its operational improvement efforts on key airports and metropolitan areas. Specifically, through the Optimization of Airspace and Procedures in the Metroplex (Metroplex) initiative, which began in fiscal year 2010, FAA has focused on airspace redesign and deploying PBN procedures—procedures that primarily use satellite-based navigation and equipment on aircraft to navigate with greater precision—in metroplexes. These metroplexes have a large effect on the overall efficiency of the NAS, because congestion or delays at one metroplex can affect NAS operations in other parts of the country. These metroplexes are shown in figure 2.

Figure 2: Metroplex Sites and Their Completion Status, as of March 2017



Sources: GAO analysis of FAA data and MapResource (map). | GAO-17-450

[a]The Core 30 airports are a set of airports in major metropolitan areas with the highest volume of traffic.

[b]FAA's Optimization of Airspace and Procedures in the Metroplex (Metroplex) initiative focuses on airspace redesign and deployment of performance-based navigation procedures in metroplexes—

geographic areas covering several airports that serve major metropolitan areas. These procedures primarily use satellite-based navigation and equipment on aircraft to navigate with greater precision.

[c]FAA "paused" work on the Phoenix metroplex in October 2015 due to legal action brought by the City of Phoenix, and does not yet have plans to resume it.

In fiscal year 2013, FAA planned to complete projects at 10 metroplexes by fiscal year 2016, but as of March 2017 FAA had completed projects at only 4 metroplexes.[17] FAA considers a metroplex "completed" when, among other things, it deploys new PBN procedures and when all air traffic controllers are trained on the new procedures. According to FAA, several factors caused the delay. FAA decided to implement ERAM before addressing metroplexes because ERAM is required for some NextGen operations. As a result, some Metroplex projects were delayed until ERAM was implemented.[18] For example, the Charlotte and Atlanta metroplexes were delayed from April 2014 until August 2015 while the Atlanta Air Route Traffic Control Center implemented ERAM. In addition, FAA changed the Metroplex program in 2015 to include enhanced community involvement and outreach activities in Metroplex projects. This change further contributed to delays. For example, according to FAA, the introduction of the community involvement initiative caused a 15 month delay in the Cleveland/Detroit Metroplex project. Under FAA's current community involvement strategy, a new Metroplex project would take about 7 months longer to complete because of community involvement activities. Further, according to FAA, sequestration and the 2013 government shutdown caused some delays due to employee furloughs and travel restrictions. In addition to the 4 completed projects, 8 other Metroplex projects are in various stages. While FAA plans to complete the current set of 12 Metroplex projects by fiscal year 2019, FAA "paused" work at one metroplex—Phoenix—in October 2015, due to legal action brought by the City of Phoenix over noise created by new PBN procedures. As of March 2017, FAA did not have plans to resume that work.

[17]FAA originally planned to complete 21 Metroplex projects by the end of fiscal year 2016, but following a 2011 schedule review determined that neither it nor the aviation community would have the personnel to stay on that schedule. In response, FAA reduced the number of metroplexes and combined some of them into a list of 13 Metroplex locations. FAA later deferred three of those locations (Boston, Chicago, and Memphis) and added two locations (Denver and Las Vegas), resulting in the current list of 12 active metroplexes.

[18]In 2012, we reported that insufficient stakeholder involvement and underestimates of the complexity of software development had led to delays in ERAM and an estimated cost increase of about $330 million. GAO-12-223. FAA attributed another delay in ERAM's completion (from August 2014 to March 2015) to the impact of sequestration.

At completed metroplexes, not all aircraft are flying PBN procedures. Although PBN procedures generally provide more efficient flight routes, controllers may continue to route air traffic on conventional routes for a number of reasons. For example, some aircraft may not have the proper equipment to use the new procedure. Further, some airline officials we interviewed reported receiving fewer benefits than expected from FAA's implementation of PBN. For example, officials at one airline told us that, at one metroplex, FAA's changes have led to that airline's flying a less efficient route into one airport, a route that requires its aircraft to use more fuel and time to land at that airport.

Some stakeholders have called on FAA to include New York in its Metroplex plans, due to its congestion and impact—such as flight delays—on the rest of the NAS, as we have previously reported.[19] In 2013, we reported that FAA chose to exclude the New York/Philadelphia metroplex because FAA did not want to initiate a new environmental review process. FAA told us in 2017 that the agency plans to focus on the northeast in the future, but does not have a current plan to implement Metroplex improvements there.

At FAA's request, RTCA established the NAC to provide advice on NextGen implementation issues.[20] FAA designated the NAC to develop aviation stakeholder priorities for NextGen implementation. These priorities included both the national implementation of NextGen as well as specific locations (such as airports) for NextGen improvements. In 2012, the Integrated Capabilities Work Group of the NAC developed priority operational improvements for major airports and metroplexes in the midterm.[21] These priority improvements included capabilities such as deploying PBN procedures that allow aircraft to take a more direct route into and out of airports, which FAA expects will save both time and fuel.

[19]GAO, *NextGen Air Transportation System: FAA Has Made Some Progress in Mid-Term Implementation, but Ongoing Challenges Limit Expected Benefits*, GAO-13-264 (Washington, D.C.: April 8, 2013).

[20]The NAC is comprised of a cross-section of senior executives from airlines, airports, general aviation, and manufacturers, with the support of aviation stakeholders from the federal government and international organizations. NAC members also include representatives from pilot and air traffic controller unions.

[21]The NAC includes a Subcommittee comprised of members with broad knowledge and expertise related to NextGen. The NAC establishes working groups to accomplish specific tasks.

In 2014, FAA and the NAC issued a Joint Implementation Plan in which FAA and industry described a set of activities that FAA and the aviation community were committed to accomplishing within the next 3 years. These activities covered four focus areas: data communications, multiple runway operations, PBN, and surface operations and data sharing. According to FAA, by the end of 2016, FAA had implemented 124 of 128 NextGen commitments it made for 2014 through 2016. For example, FAA had deployed the System Wide Information Management (SWIM) Surface Visualization Tool at five terminal radar-approach control facilities. This tool provides air traffic controllers—who are not located in the airport tower—with a real-time picture of airport surface traffic.[22] FAA and the NAC have agreed to update the Joint Implementation plan annually and develop rolling plans every 2 years to re-examine the needs of the NAS and its users and to add milestones. FAA had an additional 57 commitments for 2017 through 2019 as of the beginning of 2017, and industry had an additional 17 commitments for the same time period. In addition to these commitments, in February 2017, the NAC voted to make the Northeast Corridor – which stretches from Washington, D.C to Boston, MA and includes the New York area – the fifth area of NAC focus.

Concurrent with the work and recommendations of the RTCA's Mid-Term Implementation Task Force and the NAC, the DOT OIG and we conducted reviews of NextGen. As a result of those reviews, from fiscal year 2008 through fiscal year 2016 the DOT OIG and we issued 137 and 47 recommendations, respectively, aimed at improving the implementation of NextGen. Our analysis shows that FAA has implemented most of the recommendations related to NextGen programs from us and DOT OIG since fiscal year 2008. More specifically, FAA has implemented 39 of our 47 recommendations (83 percent), 6 recommendations are in process (13 percent), and 2 remain open (4 percent).[23] Additionally, DOT OIG has closed as implemented 103 of its 137 recommendations (75 percent) that we determined to be related to

[22]SWIM enables sharing of air traffic management-related information among diverse systems, and offers a single point of access for aviation data.

[23]Recommendations that are in process are those for which FAA has submitted information to close the recommendation, but either the information has not been fully reviewed, or we determined it does not yet sufficiently address our recommendation.

NextGen.[24] See appendix IV for an overview of the status of recommendations DOT OIG and we made related to NextGen.

Measuring and Reporting Implementation Status

FAA has faced challenges in consistently communicating the status of NextGen's implementation. In 2010, we found that while FAA had broad goals for NextGen, such as increasing capacity and reducing noise and emissions, it had not developed specific goals and outcome-based performance metrics to track the impact of and benefits realized from the entire NextGen endeavor.[25] At that time, we recommended that FAA develop an action plan to agree with stakeholders on a list of specific goals and outcome-based performance metrics for NextGen. FAA developed a set of performance metrics, which were used as a starting point with industry collaboration, and aligned them with NextGen and agency-wide goals.

Additionally, FAA launched the NextGen Performance Snapshots (NPS) website to compare key NextGen initiatives with performance outcomes at locations where NextGen technologies have been deployed. For example, with some NextGen initiatives already deployed, FAA tracks the measures and reports on airport performance at the Core 30 airports—a set of airports in major metropolitan areas with the highest volume of traffic–where NextGen technologies have been implemented. The agency plans to continue to update the NPS with additional metrics as they mature. Further, the NAC created a Joint Analysis Team which has developed outcome measures for deploying certain NextGen capabilities. For example, the team has measured the effect of efforts to update standards for separation between and among aircraft on the efficiency of operations at airports in Charlotte, Chicago, Indianapolis, and Philadelphia. The objective of this capability is to decrease the separation between and among aircraft and thereby allow more takeoffs and landings and greater efficiency and capacity for airports. FAA officials told us that FAA continues to work with industry partners to ensure that FAA is validating and verifying implementation progress of NextGen technology

[24]DOT OIG closes a recommendation after the Department of Transportation has agreed with the recommendation, has taken appropriate corrective action, and has provided DOT OIG with sufficient supporting evidence to demonstrate that the action was taken.

[25]GAO, *NextGen Air Transportation System: FAA's Metrics Can Be Used to Report on Status of Individual Programs, but Not of Overall NextGen Implementation or Outcomes*, GAO-10-629 (July 27, 2010).

and reporting successes and beneficial effects. However, some stakeholders told us that FAA continues to focus on outputs, such as the number of ADS-B ground stations deployed, instead of outcomes, such as improvements in safety, capacity, or efficiency.

FAA Plans to Complete the Majority of Planned NextGen Implementation by 2025 and within Earlier Cost Estimates

FAA Plans to Implement Most NextGen Concepts by 2025, but Has Deferred Some Activities Until after 2030

According to FAA officials, current segments of NextGen programs are generally on schedule, and FAA documents indicate that FAA plans to implement the concepts that will complete the transformation of the NAS to a NextGen system by 2025.[26] According to FAA, these timeframes are updated at least annually. FAA also has an Integrated Master Schedule for key NextGen activities; this schedule is updated at least every 3 months. In describing these concepts, FAA does not state that NextGen will be implemented or completed by 2025. Rather, FAA describes several interim milestones that are scheduled to occur between now and 2025. Taken together, the completion of these milestones—such as deploying Data Communications and expanded PBN—will result in the implementation of NextGen concepts, according to FAA. According to MITRE Corporation, the aviation industry has been able to leverage current ground-based and aircraft-based navigation capabilities to realize initial benefits of NextGen at key metroplex areas.[27] For more information on the current status of implementation of select NextGen programs and future implementation plans, see Appendix III. After 2025, FAA plans to continue enhancing technology and implementing advanced NextGen applications as part of its ongoing efforts to improve the NAS.[28]

[26]These concepts are described in FAA, *The Future of the NAS* (2016), FAA's update to its *NextGen Mid-term Concept of Operations* planning document issued in 2011. We did not validate FAA's implementation schedule and are not predicting whether FAA will meet these milestones.

[27]MITRE Corporation is a not-for-profit corporation that operates federally funded research and development centers. MITRE's Center for Advanced Aviation System Development works with FAA to develop NextGen.

[28]FAA officials pointed out that the aviation industry will not be able to use some of the more advanced capabilities that these programs are expected to provide until aircraft are equipped to use these capabilities.

In August 2017, FAA estimated that NextGen had delivered $2.7 billion in benefits through 2016. According to FAA, these benefits were realized by airlines, the FAA, and the general public, and included benefits derived from fuel savings, reductions in crew and maintenance costs, additional airline flights, FAA efficiencies, safety improvements, passenger time savings, and reductions in carbon dioxide emissions.

In addition, FAA and industry team and the MITRE Corporation have conducted studies to determine the benefits from the NextGen improvements FAA has already deployed. For example, a November 2015 MITRE Corporation analysis found that Metroplex procedural improvements resulted in fuel savings at one metroplex, although less than anticipated. Specifically, the analysis of the impact of new Metroplex procedures in the Houston Metroplex projected an annual benefit of $5.3 million in fuel savings to operators at two airports in Houston; however, the analysis also noted that these benefits were lower than the predicted savings of $8.3 million annually.[29] Similarly, June 2016 and February 2017 assessments of the effect of revised wake separation standards by the Joint Analysis Team showed positive results. These standards specify the required distance between aircraft due to the turbulence created by the air behind aircraft. The Joint Analysis Team's assessments found cost savings at four of five airports.[30] Specifically, the studies found savings for flights on congested runways, and airports could increase the frequency of takeoffs and landings.[31] The studies found a decrease in separation for arrivals at all five locations, and a decrease in separation for departures at four of the five locations, leading to increased capacity and projected cost savings of over $4.3 million annually. However, the studies also found that the effects at individual airports would depend on the type and number of aircraft at each airport.

According to FAA, some airlines and shipping companies have also reported benefits from revised wake-separation standards. FAA reports that Delta Air Lines estimated that revised separation standards at Atlanta

[29]The MITRE Corporation, *Houston Metroplex Post-Implementation Analysis* (McLean, Virginia: November 2015).

[30]The performance assessment included separation data for five airports: Charlotte Douglass International Airport; O'Hare International Airport; Chicago Midway International Airport; Indianapolis International Airport; and Philadelphia International Airport.

[31]RTCA, *Joint Analysis Team: Performance Assessment of Wake ReCat* (June 2016); RTCA, *Joint Analysis Team: Performance Assessment of Wake ReCat in Indianapolis and Philadelphia and Fuel Analysis for North Texas Metroplex* (February 2017).

increased Delta's average daily operations by 6.8 percent, among other benefits, resulting in $13.9 to $18.7 million in annual savings. Similarly, FAA reports that United Parcel Service, Inc. estimated 1.5-million gallons in annual fuel savings from revised standards at Louisville, and FedEx Corporation estimated 4.1-million gallons in fuel savings from revised standards in Memphis.

While some cost savings have already occurred, not all NextGen activities are being implemented. According to FAA officials, they have identified six NextGen activities that FAA had previously planned to complete by 2025, but has now deferred until after 2030 due to technical or operational infeasibility or changed operational needs. FAA officials explained that these applications are not in progress, and may be continually deferred, redefined, or never implemented. For example, in 2011 FAA planned to implement automated conflict-resolution aids—a mechanism to enable air traffic controllers to manage more aircraft while maintaining safety—by 2018. However, FAA's revised plan for NextGen has deferred implementation of these applications until after 2030. According to FAA, FAA deferred them for reasons such as costs outweighing prospective benefits, a lack of sufficient air traffic to justify implementation, or deployment of other capabilities that provide similar benefits. See appendix V for more information about these deferred programs.

The Current Cost Estimate for NextGen is Within Earlier Estimates, But NextGen Has Changed Over Time

FAA's current total cost estimate for implementing NextGen through 2030 is within the JPDO's 2007 estimates. In 2007, JPDO projected that through fiscal year 2025, FAA's total NextGen cost would be between $15 billion and $22 billion and that costs to the aviation industry would be between $14 billion and $20 billion. In 2016, FAA estimated the agency's cost through fiscal year 2030 at $20.6 billion—within the range of JPDO's 2007 estimate of $15 to $22 billion.[32] FAA also estimated $15.1 billion in costs for the aviation industry—also within the range of the 2007 estimate. Of the $20.6 billion in estimated costs, FAA indicated that the agency had already expended $5.8 billion through fiscal year 2014—

[32]According to FAA officials, FAA business case estimates are intended for the purpose of cost-benefit analyses and therefore estimate costs in years beyond FAA budgetary planning. These estimates include capital expenditures, research and operations, but do not include the cost of FAA staff and training.

approximately 28 percent of the estimated cost of NextGen—and projected NextGen costs of $14.8 billion from fiscal year 2015 to 2030.

Assessing prior NextGen cost estimates against current estimates is difficult because the NextGen program has changed since 2007. As previously discussed, six NextGen activities were removed for reasons such as costs outweighing benefits or insufficient air traffic to justify implementation (see appendix V). Other programs, such as PBN, were added to the NextGen program after 2007. As a result, FAA officials stated that it is somewhat coincidental that the 2016 estimate is within the range of the 2007 estimate.

We recently found that NextGen cost estimates have evolved, but not increased markedly since 2004.[33] According to FAA, NextGen cost estimates have changed in part because earlier estimates considered the cost of upgrades and enhancements, but over time estimates have also considered the cost of sustaining systems, PBN procedures, and recently, the costs associated with integrating unmanned aircraft systems (UAS) (commonly known as "drones") into the NAS.[34] FAA officials explained that FAA's current estimated total cost for the aviation industry to equip for NextGen-capable avionics—electronic equipment found in modern aircraft—is lower than earlier estimates in part because smaller aircraft are being replaced by new, larger, and better equipped aircraft, reducing the number of aircraft in the commercial fleet. According to MITRE representatives, several factors have contributed to the lower aviation industry's cost estimates, including changes in assumptions for the expected volume of commercial traffic, modifications to the cost of equipage, and reduction in uncertainty about what equipment aircraft would need.

Based on an analysis of FAA budget documents and data, we recently found that FAA received approximately $7.4 billion for NextGen from fiscal year 2004 through fiscal year 2016.[35] According to FAA officials,

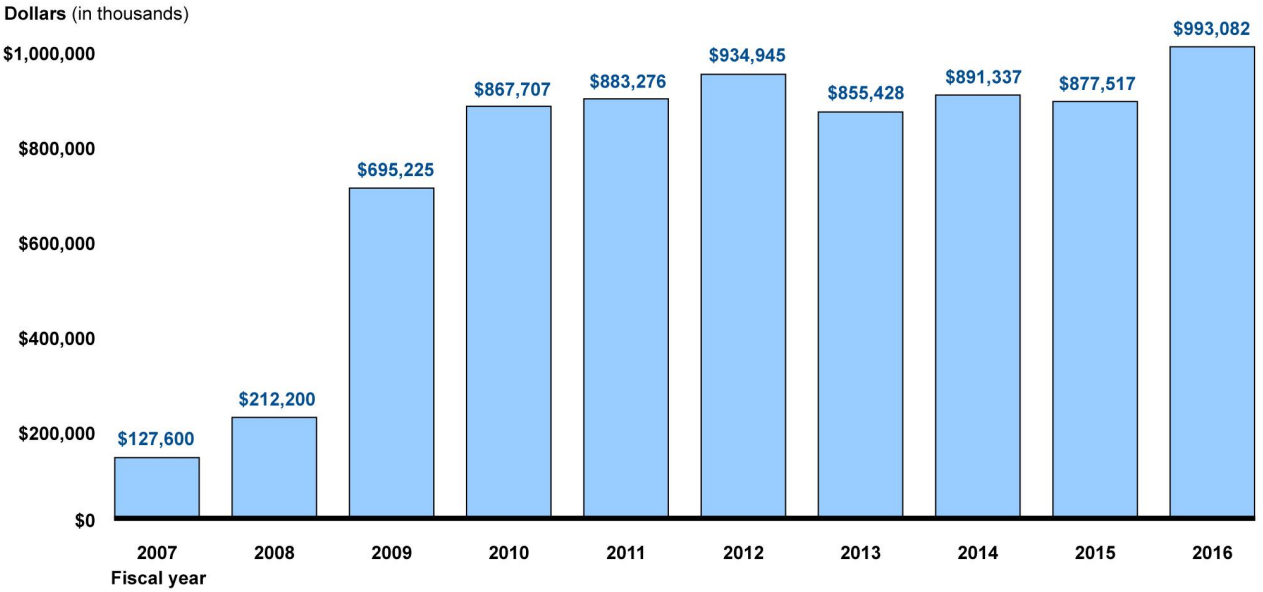
[33]GAO, *Next Generation Air Transportation System: Information on Expenditures, Schedule, and Cost Estimates, Fiscal Years 2004-2030*, GAO-17-241R (Washington, D.C.: November 17, 2016).

[34]FAA established a Drone Advisory Committee in 2016 to, among other things, recommend options for how to fund activities required to integrate drones into the NAS.

[35]GAO-17-241R. According to FAA officials, there is considerable variation in the obligation rates for facilities and equipment (F&E) projects due to the diverse nature of their procurement cycles.

operational costs of fully implemented NextGen programs are not included in these funds. Congress appropriates most of the funding to FAA from the Airport and Airway Trust Fund,[36] which receives revenues from a series of excise taxes on airline tickets, aviation fuel, and cargo shipments paid by users of the national airspace system.[37] See figure 3 for an overview of federal funds FAA has received for NextGen programs and activities.

Figure 3: Federal Funds the Federal Aviation Administration (FAA) Has Received for Next Generation Air Transportation System (NextGen) Programs and Activities, Fiscal Years 2007 through 2016



Source: GAO analysis of FAA budget submission data. | GAO-17-450

Notes: Dollar amounts presented in the figure are nominal values. From 2004 through 2006, FAA distributed $25,978,000 of its research and development funds for JPDO to plan and coordinate the transition to NextGen.

[a]According to FAA officials, the agency did not identify programs and activities as NextGen in its budget documents until 2008, but officials were able to identify three NextGen-related programs for which FAA received facilities and equipment funds for in fiscal year 2007, in addition to research and development funds it distributed to the Joint Program Development Office (JPDO) for NextGen.

[b]In 2013 FAA received $883,328,000 for NextGen, but FAA officials noted that they reprogrammed $27,900 thousand from NextGen to other programs.

[36]26 U.S.C. § 9502.

[37]The remainder of FAA's appropriations comes from the General Fund of the U.S. Treasury. The Airport and Airway Trust Fund provides funding for FAA's capital accounts, including research, engineering and development (RE&D) and facilities and equipment (F&E).

In addition to funds for NextGen, FAA has also invested in other programs on which aspects of NextGen are dependent. For example, according to FAA, the deployment of the core ERAM program cost $2.58 billion when completed in 2015, and FAA estimates that all completed and current TAMR programs will cost $3.082 billion.[38]

FAA Faces Various Challenges to Implementing NextGen

FAA faces several remaining challenges as it continues to implement NextGen, such as uncertainties regarding future funding, leadership stability, aircraft equipage, and cybersecurity issues. FAA is taking some actions to address these challenges by, for example, prioritizing and segmenting NextGen improvements into smaller pieces that each require less funding. While it is not possible to eliminate all uncertainties, FAA is adopting Enterprise Risk Management (ERM) as a tool to help it anticipate and manage risks across NextGen programs, and plans to use ERM to mitigate future risks.

FAA is Taking Steps to Address Challenges to NextGen Implementation

Uncertain Funding

Most of the aviation stakeholders we interviewed (22 of 34) told us that uncertain funding has been a challenge and has affected FAA's efforts to implement NextGen.[39] FAA officials told us that sequestration and "continuing resolutions" have had an impact on FAA's ability to plan and

[38]ERAM's original acquisition program start date was June 2003 and Terminal Automation Modernization and Replacement's start date was February 1996. The Terminal Automation Modernization and Replacement program upgrades the computer system used by air traffic controllers to provide air traffic control services in terminal airspace, the airspace immediately surrounding major airports.

[39]The numbers reported for our open-ended questions represent those stakeholders who identified a challenge to consider or suggested a change. It does not mean that the remaining stakeholders agreed or disagreed with that challenge or change.

implement NextGen.[40] Uncertain funding includes not knowing the amount of funding that will be appropriated to NextGen or when the funding will become available. From fiscal year 2011 through fiscal year 2016, Congress has passed 25 continuing resolutions that impacted funding for FAA, ranging from 1 day to 365 days, with an average of approximately 46 days. In 2014, we reported that some stakeholders told us that stops and starts associated with continuing resolutions make it difficult for FAA to carry out long-term planning and strategic development of future technologies.[41] We found that operating under continuing resolutions can also complicate agency operations and cause inefficiencies, such as leading to repetitive work, limiting agencies' decision-making options, and making trade-offs more difficult.[42] Uncertain funding was also cited by some stakeholders as a major reason for Congress to consider restructuring the FAA, which is discussed later in this report.[43]

FAA has taken steps to mitigate challenges resulting from uncertain funding. Specifically, it has prioritized NextGen improvements in collaboration with the NAC and has segmented some NextGen programs into smaller pieces that each requires less funding. In 2012, we found that FAA broke large, complex programs, such as SWIM, into smaller segments to reduce risk.[44] We previously found that this approach can improve program management by positioning FAA to make any necessary corrections earlier in development, and thus help FAA avoid

[40]A continuing resolution is an appropriations act that provides budget authority for federal agencies, specific activities, or both to continue in operation when Congress and the President have not completed action on the regular appropriations acts by the beginning of the fiscal year.

[41]GAO-14-770.

[42]In September 2009 and March 2013, we also found that continuing resolutions can create budget uncertainty for agencies about both when they will receive their final appropriation and what level of funding will ultimately be available. GAO, *Continuing Resolutions: Uncertainty Limited Management Options and Increased Workload in Selected Agencies*, GAO-08-879 (Washington, D.C.: Sept. 24, 2009); and GAO, *Budget Issues: Effects of Budget Uncertainty from Continuing Resolutions on Agency Operations*, GAO-13-464T (Washington, D.C.: Mar. 13, 2013).

[43]H.R. 2800, the Aviation Funding Stability Act, was introduced in June 2017 and seeks to provide more certain funding for aviation programs by taking the Airport and Airway Trust Fund off budget and making all Trust Fund revenues and the Trust Fund's uncommitted cash balance available immediately.

[44]GAO, *Air Traffic Control: FAA's Modernization Efforts Past, Present, and Future*, GAO-04-227T (Washington, D.C.: Oct. 30, 2003) and GAO-12-223.

costly late-stage changes. However, we also found that this approach can increase the duration and possibly the total cost of the program.[45] For example, in 2015 we found that FAA had divided capital investments for Data Communications into small segments, raising questions from the aviation industry about when FAA will fully implement Data Communications.[46]

A related funding challenge is the need for FAA to have funding sufficient to support both existing legacy system maintenance and the implementation of NextGen capabilities. As we reported in November 2015, according to FAA officials, NextGen implementation in future years is dependent on the timing and amount of future appropriations.[47] Specifically, any funding delay in one NextGen program can lead to increased costs for FAA, even if the delay does not result in a direct cost increase to a program. These cost increases occur because FAA staff must continue to manage program implementation and maintain any legacy system that the program is replacing. In addition, NextGen programs are interdependent, so a schedule delay in one program can also affect how and when other programs will be implemented.[48] In response to the challenge of maintaining the legacy system while also implementing new systems and capabilities, FAA officials told us that funding has been allocated to account for the "technical refresh" of existing systems and other maintenance related issues, and that FAA will continue to monitor and prioritize the delivery of NextGen capabilities while maintaining existing systems.[49] According to FAA officials, approximately 55 percent of FAA's current budget is used to maintain the current air traffic control system. The longer that legacy systems are maintained, there is a greater likelihood that they will continue to require increasingly large shares of the FAA budget and reduce the amount of funds available to implement NextGen. In 2011, we concluded that FAA

[45]GAO-04-227T and GAO-12-223.

[46]The Data Communications program aims to supplement existing voice communications between pilots and air traffic controllers and serve as an enabler for the NextGen operational improvements. GAO, *Aviation Finance: Observations on the Effects of Budget Uncertainty on FAA,* GAO-16-198R (Washington, D.C.: November 19, 2015).

[47]GAO-16-198R.

[48]GAO-12-223.

[49]The term technical refresh can refer to software and hardware enhancements, upgrades or modernization of system components, replacements needed to address supportability and maintainability issues, among other things.

will have to balance its priorities to ensure that NextGen implementation stays on course while also maintaining the current infrastructure that is needed to ensure the safety and reliability of the NAS.[50]

FAA Leadership Stability

NextGen program leadership has undergone significant changes that are likely to continue. Specifically, while the FAA administrator is appointed to a 5-year term, there have been four administrators since a previous administrator's term ended in September 2007, including no confirmed administrator for all of 2008 and 2012. The Deputy Administrator-Chief NextGen Officer left the position in June 2016 after 3 years in the position, and a new Deputy Administrator was sworn in in June 2017. Furthermore, since the position of Assistant Administrator for NextGen was created, in late 2011, three assistant administrators and one interim assistant administrator have filled the position. Additionally, a new Secretary of Transportation was sworn in in January 2017, and the current FAA administrator's term expires in January 2018. We previously found that programs benefit from having experienced program managers who provide consistent leadership through major phases of a program.[51] Additionally, we found that leading practices of successful organizations indicate that programs can be implemented most efficiently and effectively when managers are empowered to make critical decisions and can be held accountable for results.[52] Conversely, the absence of stable and consistent leadership may have the opposite effect on project implementation. For example, continued uncertainty about the FAA's leadership of NextGen could affect FAA's ability to manage the various efforts needed to achieve full implementation of NextGen. As we have previously reported, industry stakeholders have expressed concerns about the fragmentation of authority and lack of accountability for NextGen, two other factors that could delay its implementation.[53]

[50]GAO, *Next Generation Air Transportation System: FAA Has Made Some Progress in Implementation, but Delays Threaten to Impact Costs and Benefits*, GAO-12-141T (Washington, D.C.: October 5, 2011).

[51]GAO, *Defense Acquisition: Strong Leadership Is Key to Planning and Executing Stable Weapon Programs*, GAO-10-522 (Washington, D.C.: May 6, 2010).

[52]GAO-13-264.

[53]GAO-13-264.

Potential ATC Restructuring

Legislation introduced in June 2017 would establish a separate not-for-profit corporate entity outside of FAA to operate the nation's ATC system.[54] This proposal could affect the implementation of NextGen. For example, the change could result in more certain funding, as funding would not be subject to the federal budget process. However, other challenges could develop. In October 2016, we reported that subject area experts, aviation stakeholders, and FAA officials identified issues that will need to be considered if such a transition were to occur. Some of those issues directly affect NextGen implementation. Specifically, stakeholders told us that one issue would be the amount of time and costs required to complete a transition from FAA to another ATC operator. This transition time would include the time it could take to terminate or revise current contracts between FAA and companies that produce NextGen technologies. Another issue that stakeholders identified is how management and workforce roles and responsibilities would be defined within the new entity and FAA. For example, selected experts identified the importance of clearly delineating each organization's roles and responsibilities to ensure a smooth transition.[55] According to FAA, the transition could create some uncertainty among some employees over future workforce or organizational changes. While it is uncertain how a transition would affect NextGen implementation, the legislation includes a requirement for FAA to prioritize and track progress on some NextGen programs before the transition occurs.

Aircraft Equipage

To achieve desired benefits, NextGen requires system users such as aircraft owners and operators to equip their aircraft with new avionics that provide aircraft capabilities needed for the planned NextGen operational capabilities and services to be used effectively. For example, ADS-B uses Global Positioning System (GPS) satellites to determine an aircraft's location, speed, and other data, rather than traditional radar. ADS-B Out uses avionics installed in an aircraft to broadcast the aircraft's position, air speed, and altitude to other aircraft equipped with ADS-B and to ground

[54]Multiple countries have shifted the responsibility for providing ATC services from the national government to independent, self-financed entities with either public or private ownership.

[55]GAO, *Air Traffic Control: Experts' and Stakeholders' Views on Key Issues to Consider in a Potential Restructuring,* GAO-17-131 (Washington, D.C.: October 16, 2016).

stations, which transmit the data to air traffic control facilities.[56] FAA has mandated that, starting January 1, 2020, aircraft must be equipped with ADS-B Out to fly in most controlled airspace.[57] This deadline applies to all aircraft in the applicable airspace, including commercial aircraft, general aviation, and military aircraft.[58] In discussing challenges to implementing NextGen, 27 of the 34 aviation stakeholders we interviewed told us that factors related to equipage are a challenge for NextGen implementation. For example, officials from an aviation association told us that the primary barrier to installation of ADS-B Out when the Equip 2020 working group was created in 2014 was the cost of purchasing and installing the equipment.[59] These officials said that the price of ADS-B Out was too costly for general aviation and that the cost to equip was not declining as the deadline approached. Additionally, representatives from two airlines and two aircraft manufacturers told us that they are hesitant to equip due to concerns that FAA could change equipage standards. FAA has worked with industry and academia through the Equip 2020 working group to identify and mitigate barriers to owners equipping their aircraft and, according to FAA, has not changed equipage standards for 7 years. FAA estimates that more than 100,000 aircraft still need to equip with ADS-B Out before the January 1, 2020 deadline.[60]

As of December 2016, FAA reported that 787 U.S. air carrier aircraft were equipped with ADS-B Out, representing between 13.1 percent and 15.7 percent of all U.S. air carrier aircraft.[61] However, FAA reported that it has received equipage plans for meeting the 2020 requirement from airlines that account for 88 percent of the projected fleet. According to FAA, it continues to work with airlines to address the remaining aircraft, which include new deliveries, additional retrofits, and aircraft that may be shifted outside the U.S. market. FAA also reported that 18,292 U.S. general aviation aircraft were equipped with ADS-B Out, which represents

[56]ADS-B also includes ADS-B In, which allows aircraft to receive information transmitted from nearby aircraft and broadcasts of traffic and weather information from the ground. ADS-B In equipage is not currently mandated by FAA.

[57]14 C.F.R. § 91.225.

[58]General aviation includes all forms of aviation except commercial and military.

[59]The Equip 2020 working group includes representatives from FAA, industry, and academia. The group is designed to help reduce barriers to equipping.

[60]14 C.F.R. § 91.225.

[61]Percentage range based on FAA estimates of 5,000-6,000 US air carrier aircraft.

between 11 percent and 18 percent of all U.S. general aviation aircraft.[62] To encourage aircraft owners and operators to equip with ADS-B Out, prior to the January 1, 2020, deadline, FAA announced a $500 rebate in September 2016 for 20,000 general aviation aircraft owners and operators who equip with ADS-B Out. According to FAA, a minimal rule-compliant system costs approximately $2,000, plus installation costs. The Equip 2020 working group performed a survey of aircraft owners and found that getting costs below $2,000 would encourage many price-sensitive owners to equip. As such, the FAA chose $500 as an amount that would get the price down to that more-attractive range, and according to FAA, this amount also maximized the total number of rebates the agency could distribute, based on total funding approved for the program. FAA officials said it could be a problem if owners wait until 2019 to get equipped since there are a limited number of facilities and technicians available to equip airplanes. Additionally, once aircraft are equipped with new avionics technology, FAA must ensure that the avionics were properly installed and meeting performance standards.[63]

Similar to ADS-B, before aircraft owners and operators can benefit from the capabilities of Data Communications, their aircraft must be equipped with Data Communications avionics equipment. FAA has achieved its 2019 goal for equipping 1,900 domestic air carrier aircraft with Data Communications avionics. For example, according to FAA, as of August 2017, more than 3,150 domestic air carrier aircraft were equipped for Data Communications. As with ADS-B Out, FAA established an incentive fund to encourage early adoption of the technology, and eight airlines signed agreements to equip their aircraft under the incentive program.[64]

New Entrants into the NAS

According to 16 of 34 aviation stakeholders we interviewed, the need to integrate new entrants—UAS and commercial spacecraft—into NextGen efforts is a challenge to implementing NextGen. Integrating new entrants

[62]Percentage range based on FAA estimates of 100,000-160,000 US general aviation aircraft.

[63]FAA provides an automated tool in order to assist aircraft owners, operators, and avionics shops with the validation of the performance of the ADS-B Out equipment installed on aircraft.

[64]Of the more than 3,150 domestic air carrier aircraft equipped with Data Communications as of August 2017, over 1,450 were through the incentive program and nearly 1,700 were outside the program.

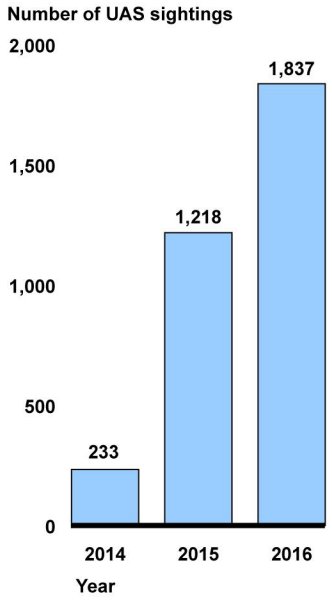
could have both budget and program implications. When the original planning for NextGen was developed, UAS were not generally included in the planning. In June 2016, FAA finalized the first set of federal aviation regulations that established the regulatory framework for small UAS operations and allowed routine commercial use of small UAS at 400 feet and below and within the operator's line-of-sight.[65] This regulation went into effect in August 2016.[66] FAA statistics indicate that there are more than 770,000 registered drone operators in the United States. Applying lessons learned about the importance of early and continued involvement of stakeholders, FAA established the Drone Advisory Committee (DAC). The DAC consists of government officials and predominantly industry stakeholders and advises FAA as it works to expand small UAS operations in the NAS. This expansion could include operations over people, at night, and beyond the visual line-of-sight of the operator, and the transportation of persons and property.[67] The increased use of drones has resulted in an increase in the number of UAS sightings, which occur when pilots, law enforcement, and others report a possible encounter with a UAS, many of which FAA is concerned pose a safety hazard to manned aircraft. The number of reported sightings increased about five-fold from 233 in 2014 to 1,218 in 2015 and increased by about another 50 percent in 2016 to 1,837 (see fig. 4).

[65]81 Fed. Reg. 42064 (June 28, 2016).

[66]14 C.F.R. Part 107.

[67]We are currently reviewing FAA's oversight of UAS in a separate effort and expect to issue a report in November 2017.

Figure 4: The Federal Aviation Administration's (FAA) Annual Unmanned Aircraft Systems Sightings, 2014 through 2016



Source: GAO review of Federal Aviation Administration documents. | GAO-17-450

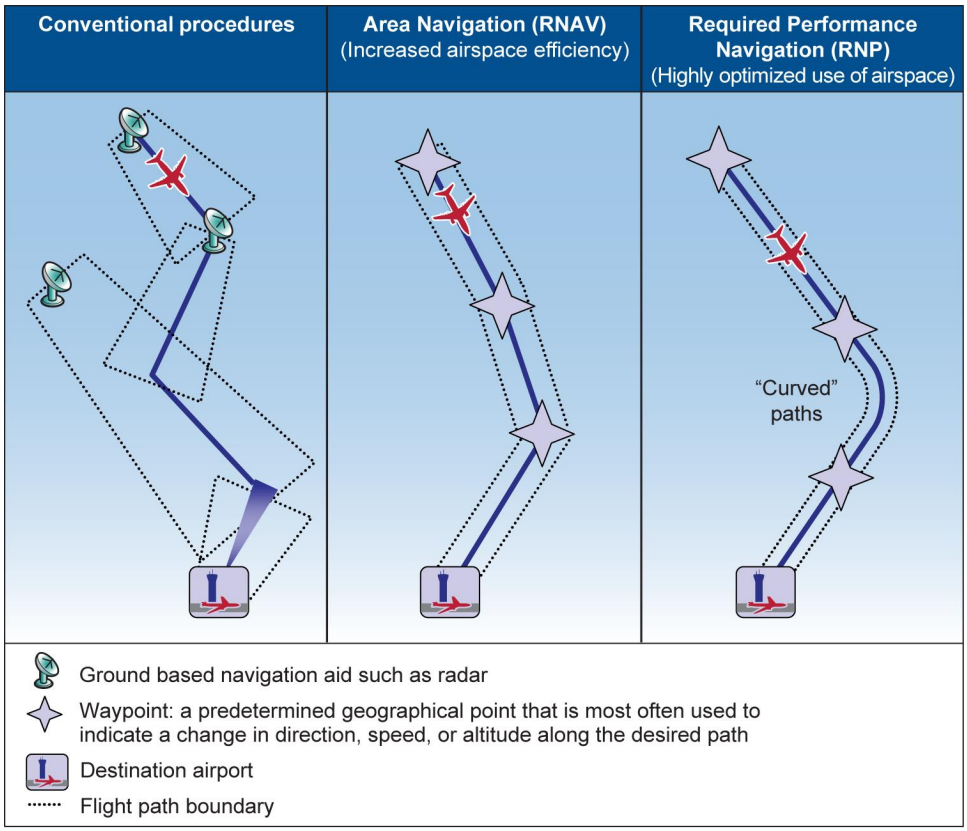
FAA must also integrate commercial space launches into the NAS. The commercial space industry delivers cargo to the International Space Station as well as launching satellites. In recent years, U.S. companies have conducted a number of licensed launches and reentries. According to FAA data, the first licensed reentry occurred in October 2014, and FAA has licensed a total of seven entries through June 2017. During this same time period, FAA has licensed 33 commercial space launches. As companies develop the capability to conduct other types of launches, such as delivering crew for the National Aeronautics and Space Administration's commercial space programs and conducting space tourism, the number of launches and reentries affecting U.S. airspace is expected to grow. If the expected growth occurs, NextGen will need to accommodate spacecraft launches and re-entries as they go through the national airspace system.

Community Outreach for Environmental Concerns

Through PBN, FAA uses satellite-based guidance to route aircraft and to improve approaches at airports, which can result in changes to flight paths. Specifically, aircraft using PBN can begin to fly a more direct and predictable path into or out of an airport. As a result, parts of a community that may not have experienced aircraft noise in the past may begin to

experience noise. (See fig. 5 for an illustration of these procedures.) This new noise can also be more prevalent for some parts of a community as airplanes fly a more direct and predictable path into or out of an airport and are therefore overhead more frequently. Consequently, aircraft noise has resulted in some public opposition to NextGen.

Figure 5: Procedures Using Conventional Equipment and Performance-Based Navigation Technologies



Sources: FAA and GAO. | GAO-17-450

FAA officials have acknowledged that, in some locations, there is significant public resistance to redesigning airport arrival and departure routes to take advantage of PBN. FAA has enhanced community outreach efforts to help address concerns about aircraft-related noise. For example, in February 2016, FAA completed the development of its Community Involvement Manual to give FAA staff an understanding of the value of community involvement. The manual also describes practices

and effective techniques for engaging in dialogue and collaboration with communities affected by FAA actions.[68] Additionally, in June 2016, a NAC task group made recommendations to FAA for community outreach to assist FAA and industry with the growing environmental challenges associated with PBN implementation. For example, the task group recommended that FAA should form a specialized Community Outreach Team trained to conduct outreach both from the aspect of retaining conformity with legal and regulatory requirements as well as communicating in an effective manner.

International Harmonization

FAA must ensure that its NextGen programs are compatible with programs in other countries. This compatibility is known as "international harmonization."[69] Other countries are in the process of updating their air traffic control systems, and international coordination is necessary to ensure that systems and procedures are interoperable.[70] In July 2015, we reported that as such modernization efforts proceed worldwide, collaboration—both within FAA and with domestic and international aviation stakeholders—will be critical to developing modernized systems and procedures that allow aircraft to seamlessly transition from one system to another, help enhance safety, and ensure the greatest operational and performance benefits to aviation users. We found that FAA has taken positive steps to better coordinate its NextGen interoperability efforts across the agency. These steps include the development of an international strategic plan and establishment of two internal bodies to guide and monitor international activities. However, we also found that FAA lacked a process for routinely and comprehensively assessing potential NextGen interoperability risks. As a result, we recommended that FAA implement a more effective international strategy

[68]FAA, *Community Involvement Manual* (Washington, D.C. Feb. 2016). The Consolidated Appropriations Act of 2016 required FAA to update this manual. Pub. L. No. 114-113, 129 Stat. 2242, 2840 (2015).

[69]Harmonization is the agreement on and implementation of compatible standards, procedures, and technologies (and associated policy) to ensure interoperability.

[70]FAA has entered into a memorandum of cooperation between the United States and the European Union that covers "SESAR-NextGen Cooperation for Global Interoperability." FAA also leads the International Civil Aviation Organization's initiative to update the Global Air Navigation Plan with the Aviation System Block Upgrade program to drive international operability.

for achieving NextGen interoperability with other nations.[71] FAA is in the process of addressing this recommendation.

Cybersecurity Concerns with a Highly Integrated and Connected System

In April 2015, we reported that FAA faces cybersecurity challenges in at least three areas: (1) protecting air-traffic control (ATC) information systems, (2) protecting aircraft avionics used to operate and guide aircraft, and (3) clarifying cybersecurity roles and responsibilities among multiple FAA offices.[72] Through NextGen, FAA is shifting the ATC system from a point-to-point communications system to an Internet-based, interconnected system; a process of changeover that increases cybersecurity risks. We found that FAA is making strides to address these risks, including implementing an enterprise approach for protecting its systems from cyber-attack by both internal and external threats in accordance with standards of the National Institute for Standards and Technology and other cybersecurity leading practices. However, FAA had not developed a threat model that would describe the landscape of security risks to FAA's information systems. We recommended that FAA, as a first step to developing an agency-wide threat model, assess the potential cost and timetable for developing such a model and the resources required to maintain it. In January 2016, FAA issued FAA Threat Model Schedule and Cost Estimate, Report of Finding, which stated that FAA is developing an Enterprise Threat Model that will be a holistic approach to the identification and assessment of cybersecurity threats, hazards and vulnerabilities. The report included a detailed schedule and cost estimate for developing the model.

FAA Has Adopted Enterprise Risk Management to Identify Potential Risks to NextGen

FAA has adopted ERM as a framework to manage risk across NextGen programs. ERM is a forward-looking management approach that allows

[71]GAO, Next Generation Air Transportation System: Improved Risk Analysis Could Strengthen FAA's Global Interoperability Efforts, GAO-15-608 (Washington, D.C.: July 29, 2015).

[72]GAO, *Air Traffic Control: FAA Needs a More Comprehensive Approach to Address Cybersecurity as Agency Transitions to NextGen*, GAO-15-370 (Washington, D.C.: April 14, 2015).

an agency to assess risks and opportunities that could affect the achievement of its goals and the agency's ability to achieve results. The Office of Management and Budget (OMB) considers ERM to be an effective agency-wide approach to addressing the full spectrum of an organization's risks by understanding the combined impact of risks. In July 2016, OMB issued an update to its Circular A-123 that required federal agencies to implement ERM to better ensure their managers are effectively managing risks that could affect the achievement of agency strategic objectives. While this requirement is only at the department level, FAA has established ERM for NextGen in addition to any DOT-wide efforts.

ERM is intended to yield an "enterprise-wide," strategically-aligned portfolio view of organizational challenges that provides better insight about how to most effectively prioritize resource allocations to ensure successful mission delivery.[73] Three organizations within FAA have established risk management efforts that, taken together, would manage risks at each of the program, portfolio, and enterprise levels. The efforts constitute a three-tiered structure for managing risks to NextGen. Program risks are elevated to the portfolio level if they cannot be effectively managed by a program, and portfolio risks are elevated to the enterprise level if they cannot be effectively managed by the portfolios. Risks are also transferred to a lower level if they can be managed at that level. Each level also seeks to identify, assess, and manage risk at its own level. In December 2016, we issued a report that identified essential elements and good practices for ERM.[74] These and other documents provide guidance for agencies seeking to implement ERM which can assist agencies in managing risks and challenges related to delivering the organization's mission. In this review, we found that it was too early to assess FAA's efforts against our identified good practices.

[73]OMB, Circular No. A-11, *Preparation, Submission, and Execution of the Budget* pt. 6, §§ 270 (July 2016).

[74]GAO, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk*, GAO-17-63 (Washington, D.C.: December 1, 2016).

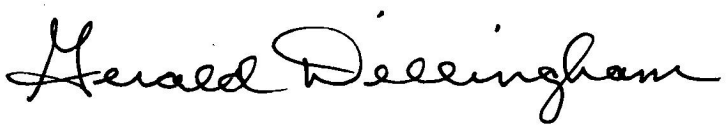
Agency Comments

We provided a draft of this report to the Department of Transportation for review and comment. The Department provided technical comments, which we incorporated, as appropriate.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the appropriate congressional committees, Secretary of Transportation, and other interested parties. In addition, the report will be available at no charge on the GAO web site at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at 202-512-2834 or dillinghamg@gao.gov. Contact points for our Office of Congressional Relations and Public Affairs may be found on the

last page of this report. GAO staff who made major contributions to this report are listed in appendix VI.



Gerald L. Dillingham, Ph.D.
Director, Civil Aviation Issues

Appendix I: Objectives, Scope, and Methodology

Our objective was to assess the status of the Federal Aviation Administration's (FAA) efforts to implement the Next Generation Air Transportation System (NextGen). For our review, we addressed (1) how FAA has implemented NextGen and addressed implementation challenges; and (2) the challenges, if any, that remain for implementing NextGen, and FAA's actions to mitigate these challenges.

To address both of these objectives, we reviewed FAA's planning documents for NextGen and FAA reports, briefings, and other documents related to ongoing NextGen efforts. To determine how FAA has implemented NextGen and addressed challenges to its implementation, we reviewed FAA implementation actions for developing and deploying elements of NextGen programs, including programs in the areas of communications, automation, navigation, surveillance, and weather. We also assessed FAA's efforts to address commitments it made in 2014 to implement actions in four focus areas—data communications, multiple runway operations, PBN, and surface operations and data sharing—over a 3-year period. FAA and the aviation industry identified these commitments as part of a collaborative effort between FAA and the NextGen Advisory Committee (NAC), which includes representatives from industry and FAA's senior leadership and advises FAA on the implementation of NextGen. Additionally, we reviewed reports issued by GAO, the Department of Transportation's (DOT) Office of Inspector General (DOT OIG), and NextGen advisory groups. We also reviewed NextGen-related recommendations made by GAO, the DOT OIG, and NextGen advisory groups such as the NAC, RTCA, and MITRE's Center for Advanced Aviation System Development, and assessed FAA's efforts to address these recommendations.[1] We then conducted a detailed analysis of NextGen-related recommendations made by GAO and the DOT OIG from fiscal year 2008 to fiscal year 2016 and determined the status of each individual recommendation. We also assessed the current

[1]RTCA (founded as the Radio Technical Commission for Aeronautics in 1935) is a public-private partnership that provides a forum for developing consensus among competing interests on aviation modernization issues, including providing industry recommendations for FAA.

cost estimates for implementing NextGen through 2030, and compared them to earlier estimates provided by the Joint Planning and Development Organization (JPDO) in 2007. In addition, we interviewed FAA officials from the NextGen Office and its Interagency Planning Office, the Office of Aviation Safety (AVS), and the Air Traffic Organization (ATO).

To determine the challenges, if any, that remain for implementing NextGen, and FAA's actions to mitigate these challenges, we interviewed FAA officials from the NextGen Office, AVS, and ATO. Additionally, to determine actions FAA is taking to address risks to NextGen, we reviewed FAA's risk management documents and interviewed FAA's NAS Systems Engineering Services Office, an organization within the Office of NextGen responsible for designing and maintaining the FAA's NAS Enterprise Architecture and providing systems engineering related to NextGen, which has established a process to manage risks to NextGen.

To obtain aviation stakeholders' perspectives on NextGen challenges and FAA efforts for both of our objectives, we interviewed a non-probability sample of 34 aviation stakeholders (see table 3). We created an initial list of stakeholders using internal knowledge of the aviation industry. We further developed the list of stakeholders by identifying industry stakeholders that have made NextGen-related recommendations to FAA, conducting a literature review of NextGen issues. We also included stakeholders based on interviewee responses to our question on whom else they thought we should speak with, as well as stakeholders that experienced the effects of changes from NextGen. Specifically, we wanted to obtain perspectives from individuals and organizations with direct experience, as users, or knowledge, through research or study of NextGen. We divided stakeholders into the following eight categories: airlines, airports, aviation experts and other relevant organizations, former FAA officials, research and development organizations, general aviation, labor unions and professional associations, and manufacturers and service providers. We used a semi-structured interview format with open-ended questions to obtain aviation stakeholder perspectives on the status of NextGen implementation efforts, factors that have affected NextGen implementation, challenges that still remain, and FAA efforts to address such factors and challenges.

Table 3: List of the 34 Aviation Industry Stakeholders We Interviewed

Industry	Type	Stakeholder

Industry	Type	Stakeholder
Airlines	Associations	Airlines for America (A4A)
	Cargo	Federal Express (FedEx)
	Passenger	Alaska Airlines
		American Airlines
		Delta Air Lines
		JetBlue Airlines
		Southwest Airlines
Airports	Associations	Airports Council International – North America (ACI-NA)
Airports	Airport Operators	Port Authority of New York and New Jersey (Kennedy International Airport, Newark Liberty International Airport, LaGuardia Airport, Stewart International Airport, Teterboro Airport, and Atlantic City International Airport)
		Charlotte-Douglas International Airport
Aviation Experts and Other Relevant Organizations		Dr. George Donohue, Systems Engineering & Operations Research, George Mason University
		Dr. Mark Hansen, Civil & Environmental Engineering, University of California, Berkley
		Dr. John Hansman, Aeronautics and Astronautics, Massachusetts Institute of Technology
		Mr. Steve Fulton, Sandel Aviation
		RTCA (formerly known as Radio Technical Commission for Aeronautics)/NextGen Advisory Committee (NAC)
Former FAA Administrators and Managers		Marion Blakey, Former Administrator (2002-2007)
Former FAA Administrators and Managers		Russell Chew, Former Chief Operations Officer, Air Traffic Organization (2003-2007)
Research & Development Organizations		MITRE Center for Advanced Aviation System Development (CAASD)
Research & Development Organizations		Research, Engineering, & Development Advisory Committee (REDAC)
General Aviation		Aircraft Owners and Pilots Association (AOPA)
		National Air Transportation Association (NATA)
		National Business Aviation Association (NBAA)
Labor Unions and Associations	Air Traffic Controllers	National Air Traffic Controllers Association (NATCA)
Labor Unions and Associations	Pilots	Airline Pilots Association (ALPA)
Labor Unions and Associations	Support	Professional Aviation Safety Specialists (PASS)
		Aeronautical Repair Station Association (ARSA)
Manufacturers and Service Providers	Associations	Aerospace Industries Association (AIA)
		Aircraft Electronics Association (AEA)

Industry	Type	Stakeholder
Manufacturers and Service Providers	Aviation Equipment	Harris Corporation
		Honeywell Aerospace
		Mosaic ATM
		Thales Air Traffic Management North America
Manufacturers and Service Providers	Commercial Planes	Boeing, Inc.
Manufacturers and Service Providers	Small Aircraft	Gulfstream Aerospace Corporation
		Textron Inc.

Source: GAO. | GAO-17-450

We used open-ended questions to engage the stakeholders in a conversation about the challenges they considered most important and relevant. To determine the common themes that we are reporting on, we conducted a content analysis of each of the interviewees' responses. The numbers reported for our open-ended questions represent those stakeholders who, during our interviews, identified a challenge to consider or suggested a change. The reported numbers do not mean that the remaining stakeholders agreed or disagreed with that challenge, change, or issue. In our discussion of stakeholder views obtained through our open-ended questions, we aggregated their responses and reported on stakeholders' perspectives in general. The results of our interviews are not generalizable to the industry as a whole. Based on stakeholder responses, we identified a set of challenges and asked FAA to provide their perspective on each challenge and any actions FAA is taking to address it.

We conducted this performance audit from November 2015 to August 2017 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: Select Planning and Implementation Documents

Since the passage of the Vision 100 Act in December 2003, the planning for NextGen has evolved from a high-level vision developed by the Joint Planning and Development Organization to detailed implementation plans currently being implemented by the Federal Aviation Administration.[1] The following table provides an overview of these documents.

Table 4: Select Planning and Implementation Documents for the Next Generation Air Transportation System, 2004-2016

Document	Date	Issuer	Description
Integrated National Plan	December 2004	Joint Planning and Development Organization	A plan setting forth a vision statement, system goals, performance characteristics, operational concepts, and transformation strategies, among other things, for the Next Generation Air Transportation System (NextGen).
Concept of Operations for the Next Generation Air Transportation System	Version 2.0 issued June 2007	Joint Planning and Development Organization	A document describing the Joint Planning and Development Organization's contemporary vision for how the NextGen system would operate in 2025 and beyond and identifying key research and policy issues.
Enterprise Architecture for the Next Generation Air Transportation System	Version 2.0 issued June 2007	Joint Planning and Development Organization	A document that was a technical description of the NextGen system, and that was designed to provide a common tool for planning the complex, interrelated systems that would make up NextGen.

[1]The Consolidated Appropriations Act of 2014 did not include funding for the JPDO, resulting in its closure. FAA has created an Interagency Planning Office within FAA to replace certain functions of the JPDO and coordinate federal investment in NextGen across agencies.

Document	Date	Issuer	Description
Integrated Work Plan for the Next Generation Air Transportation System	Version 0.1 issued July 2007	Joint Planning and Development Organization	A document describing the capabilities needed to transition to NextGen from the current system and providing the research, policy, regulation, and acquisition timelines necessary to achieve NextGen by 2025.
NextGen Implementation Plan	First plan issued June 2008 (updated annually)	Federal Aviation Administration	A document providing an overview of the Federal Aviation Administration's (FAA) ongoing transition to NextGen, laying out FAA's vision for NextGen, and providing a status report on NextGen deployments, capabilities, and benefits.
NextGen Mid-Term Implementation Task Force Report	September 2009	RTCA NextGen Mid-Term Implementation Task Force	A report by a task force of aviation stakeholders that included recommendations to FAA focused on key improvements that could be implemented with existing technologies and capabilities in the mid-term, which was by 2018.
FAA Response to Recommendations of the RTCA NextGen Mid-Term Implementation Task Force	January 2010	Federal Aviation Administration	A document describing how FAA intended to respond to the RTCA Mid-Term Implementation Task Force's recommendations.
NAS Segment Implementation Plan	First plan issued in 2010 (updated annually)	Federal Aviation Administration	An internal planning document that includes milestones for NextGen programs and execution.
NextGen Mid-Term Concept of Operations for the National Airspace System	March 2011	Federal Aviation Administration	A document presenting a high-level concept of operations for the national airspace system (NAS) in the mid-term. The document provided an operational view of the system and individual operating concepts, and presented high-level descriptions of visionary concepts to be researched as possible solutions for NextGen.
NextGen Priorities Joint Implementation Plan	October 2014	Federal Aviation Administration, in collaboration with the NextGen Advisory Committee	A document, prepared in collaboration with the NextGen Advisory Committee—an organization of aviation stakeholders that advises FAA on NextGen implementation—that targeted four focus areas: multiple runway operations, performance-based navigation, surface operations and data sharing, and data communications. The plan contained commitments in those focus areas that FAA and industry agreed to implement over the next three years.

Document	Date	Issuer	Description
The Future of the NAS	June 2016	Federal Aviation Administration	A document describing the NextGen concepts and activities planned to be delivered by 2025 based on concept evolution and technology assessments conducted since the Mid-Term Concept of Operations. The document is intended to guide future research, planning, and investment decisions, and help FAA and industry plan for the future and prioritize future investments.
NextGen Priorities Joint Implementation Plan Rolling Plan	September 2016	Federal Aviation Administration, in collaboration with the NextGen Advisory Committee	A document containing additional FAA and industry commitments for 2017 through 2019.
PBN NAS Navigation Strategy 2016	September 2016	Federal Aviation Administration	A document describing FAA's strategy for transitioning to an NAS where performance-based navigation is used as the basis for daily operations.

Source: GAO analysis of Federal Aviation Administration and RTCA documents. | GAO-17-450

Appendix III: Selected Programs in the Next Generation Air Transportation System (NextGen)

This appendix contains information on selected NextGen programs, including the program's purpose, the progress of each program, and the Federal Aviation Administration's future plans for implementing the program.

Table 5: Selected Programs in the Next Generation Air Transportation System (NextGen)

Communications	Purpose, Progress and Future Plans
Aeronautical Information Management Modernization (AIMM)	Purpose: AIMM will provide aviation users with digital aeronautical information that conforms to international standards and supports NextGen objectives. Aeronautical information consists of critical information required for safe operation of the National Airspace System (NAS), such as airport configuration data.
	Progress and Future Plans: FAA implemented digital Notices to Airmen—Federal Aviation Administration (FAA) notices to pilots of information that is time-critical and is either of a temporary nature or is not known far enough in advance to permit publication on aeronautical charts or other operation publications—and Central Altitude Reservation Function (CARF) system capabilities. The CARF coordinates military and civilian altitude reservations for operations in the NAS. Future planned capabilities include a platform to deliver aeronautical information across the NAS; a portal consisting of a data query, display, and analysis tool connected to the platform; active runway/airport configuration data; and increased integration with automation, among other things.
Data Communications (Data Comm)	Purpose: Data Comm will supplement the voice communications currently used to relay information between air traffic controllers and aircraft with pre-scripted email-like messages. Data Comm will provide communication infrastructure enhancements and serve as an enabler for NextGen operational improvements. FAA expects that Data Comm will increase efficiency and reduce the potential for miscommunication between controllers and aircraft.
	Progress and Future Plans: As of December 2016, FAA completed deployment of Data Comm's departure clearance service, which provides automated assistance for requesting and delivering initial and revised departure clearances, at 55 air traffic control towers. FAA expects to begin deploying Data Comm services at en route centers—air traffic control facilities responsible for guiding aircraft at higher altitudes—in July 2019, and complete deployment in December 2023. FAA plans to begin implementing an Aeronautical Telecommunications Network (ATN) ground system to support advanced Baseline 2 avionics in 2030. ATN Baseline 2 is a more advanced digital communications infrastructure, providing additional capabilities for connecting different types of ground applications to corresponding air applications. FAA expects to begin implementing enhancements to en route and terminal ground automation systems software to support message exchange with Baseline 2 avionics in 2030-2035.

Communications	Purpose, Progress and Future Plans
National Airspace System Voice System (NVS)	Purpose: NVS will replace the FAA's voice switches, which currently use analog point-to-point voice switching technology, with a nationwide network that uses digital Voice over Intranet Protocol (VoIP) technology. FAA expects that NVS will increase resiliency and capacity by allowing FAA to shift workload between air traffic control facilities during unexpected events or poor weather conditions, allow traffic managers to monitor the voice system from a central location, and help support airspace redesign and future NextGen air traffic control operations.
	Progress and Future Plans: FAA completed a critical design review of the NVS hardware and software in June 2015, a review that allowed FAA to proceed to a testing phase. FAA expects to have initial operating capability at the first key site in fiscal year 2019, and to conduct production and deployment of NVS operational systems from 2020 through 2027.
System Wide Information Management (SWIM)	Purpose: SWIM provides standards, hardware, and software to enable information management and data sharing to support NextGen. SWIM enables sharing of air traffic management-related information among diverse systems, and offers a single point of access for aviation data. Among other benefits, SWIM replaces unique interfaces with a standards-based data exchange, provides enterprise security and monitoring, provides access to aviation data through a single connection, and facilitates increased common situational awareness across the NAS.
	Progress and Future Plans: FAA has introduced Service Oriented Architecture (SOA) implementation and completed deployment of nine data publishing and information exchange capabilities in September 2015. SOA is a standards-based, technology-neutral set of principles and methodologies for designing and developing software in the form of interoperable services. FAA is currently deploying SOA services, including NAS Enterprise Messaging Service, the information sharing infrastructure that enables publishing and sharing NAS data, as well as enterprise service management, interface management, and security services, and expects to complete the deployment in December 2017. FAA plans to deploy additional services, including security controls, enterprise monitoring, increased access to data, and a query engine and data aggregation utility, through June 2021.

Navigation	Purpose, Progress and Future Plans
Performance-Based Navigation (PBN)	Purpose: PBN provides new routes and procedures that primarily use satellite-based navigation and equipment on aircraft to navigate with greater precision. The benefits of PBN include shorter, more direct flight paths; improved airport arrival rates; enhanced controller productivity; increased safety due to repeatable, predictable flight paths; fuel savings; and reduced environmental impacts. Through its Optimization of Airspace and Procedures in the Metroplex (Metroplex) initiative, FAA has focused much of its PBN procedure development on priority metroplexes—geographic areas covering several airports that serve major metropolitan areas—with airport operations that have a large effect on the overall efficiency of the NAS.
	Progress and Future Plans: FAA has deployed thousands of PBN procedures across the NAS. As of March 2017, FAA had completed Metroplex projects at 4 metroplexes: Washington, D.C., Houston, North Texas, and Northern California. FAA's key focus for the near term (2016-2020) is on increasing the use of PBN procedures and services, in addition to continuing to deploy new procedures. From 2021-2025, the focus will be on expediting the delivery, use, and maintenance of PBN. From 2026-2030, FAA will focus on completing divestment of legacy infrastructure, resulting in an NAS where PBN would be the standard method of navigation by 2030.
Wake Turbulence Re-Categorization (Wake Recat)	Purpose: Wake Recat will develop and implement new wake separation standards—standards for the required distance between aircraft due to the turbulence created by the vortices of air behind aircraft—to obtain more efficient spacing and sequencing of aircraft while maintaining safety. Decreasing the separation between aircraft can allow more flights into and out of airports and through congested air corridors, and increase efficiency and airport capacity.

Navigation	Purpose, Progress and Future Plans
	Progress and Future Plans: FAA has completed development of wake separation standards that classify aircraft into six categories according to their wake turbulence characteristics, such as wingspan, and the current fleet mix for U.S. airports, and has begun implementing those standards at U.S. airports. Previous wake separation standards separated aircraft primarily based on their weight. FAA has also developed standards for leader-follower pairs for 99 percent of all aircraft types operating in the United States, and plans to begin initial implementation for evaluation of those standards in fiscal year 2017.

Surveillance	Purpose, Progress and Future Plans
Automatic Dependent Surveillance-Broadcast (ADS-B)	Purpose: ADS-B uses Global Positioning System (GPS) satellites to determine an aircraft's location, speed, and other data, rather than traditional radar. ADS-B Out uses avionics installed in an aircraft to broadcast the aircraft's position, air speed, and altitude to other aircraft equipped with ADS-B and to a network of ground stations, which relays the data to air traffic control displays. ADS-B In allows aircraft to receive information transmitted from nearby aircraft and broadcasts of traffic and weather information from the ground.
	Progress and Future Plans: In September 2014, FAA completed NAS-wide deployment of ADS-B for surveillance and air traffic services supporting en route, terminal, and airport surface operations, and in March 2016 FAA completed an expansion to provide coverage for all of the Gulf of Mexico. FAA plans to complete work to allow aircraft to more easily access efficient altitudes in oceanic airspace in fiscal year 2017 and a further range of ADS-B applications and capabilities in September 2020. FAA plans to make a decision in March 2018 on whether to approve a set of future capabilities, including a surveillance backup strategy, for implementation. FAA also plans to make a series of such decisions regarding Interval Management, which consists of a suite of tools for use in combination by air traffic controllers and ground crews to more precisely and efficiently manage inter-aircraft spacing, with the first decision planned for fiscal year 2020.

Automation	Purpose, Progress and Future Plans
Collaborative Air Traffic Management-Technologies (CATM-T)	Purpose: CATM-T provides capability enhancements to the existing Traffic Flow Management System (TFMS). TFMS is a data exchange system that supports the management and monitoring of national air traffic flow, and is the primary source for capturing and disseminating air traffic information. CATM-T enhancements enable a more collaborative environment among air traffic controllers and airline operators, improve traffic flow prediction in the NAS and the usability of collaborative decision making tools, and improve FAA's ability to collect data for performance measurement and metrics reporting.
	Progress and Future Plans: FAA completed deployment of an initial set of CATM-T capabilities in June 2011, including capabilities that identify en route constraints and meter the demand through the constrained area and that maximize the use of departure slots during ground delay programs, which delay aircraft at departure airports in order to manage demand and capacity at arrival airports. In March 2015, FAA completed deployment of a set of CATM-T capabilities that improve management of unscheduled flights during ground delay programs, identify constrained airspace and assist traffic planners with formulating solutions, and allow transmitting re-routes to air traffic control automation, among other things. In May 2016, FAA deployed a set of capabilities that provide increased situational awareness and improved constraint prediction and modernize the decision support tools suite used by traffic managers. FAA plans to make decisions on whether to approve further sets of CATM-T capabilities for implementation in June 2017 and December 2018.
En Route Automation Modernization (ERAM)	Purpose: ERAM is FAA's computer system for en route air traffic control. Although ERAM was not considered part of NextGen, FAA considers the technical improvements it is making to ERAM to be part of NextGen because they are critical to the delivery of certain NextGen capabilities and programs.
	Progress and Future Plans: FAA completed nationwide deployment of the base ERAM program, which replaced the hardware and software of the prior Host Computer system, in March 2015. FAA used the Host Computer System at en-route centers to process radar data and to allow controllers to monitor and separate traffic. FAA expects to complete replacement of some ERAM equipment that has become obsolete in fiscal year 2021, and complete deployment of software enhancements for en route controllers that will improve the efficiency and effectiveness of en route sector operations in fiscal year 2022.

Automation	Purpose, Progress and Future Plans
Terminal Flight Data Manager (TFDM)	Purpose: TFDM will provide tower air traffic controllers and FAA traffic managers with NextGen decision support capabilities for the airport surface that integrate flight, surveillance, and traffic management information. TFDM will automate manual flight data processes to enable enhanced data sharing between air traffic control facilities, and enhance efficiency on the airport surface. TFDM will transition from paper flight strips to electronic flight data, which will facilitate enhanced flight data exchange between controllers and aviation partners such as airline flight operations centers and airport operators. TFDM will also include a scheduler/sequencer capability that will transition performance of airport surface operations from a "first come, first served" model to a model that allocates taxi clearances to minimize taxi distance and time.
	Progress and Future Plans: The development and production contract for TFDM was awarded in June 2016. FAA plans to begin deploying initial operating capability in 2020 and plans to complete it in 2028. However, FAA has begun early implementation of some elements of TFDM, including completing deployment of a tool that provides air traffic controllers with a picture of airport surface traffic in real time at 11 sites as of January 31, 2015 and deploying an Advanced Electronic Flight Strip system, a prototype system that replaces the paper strips controllers use to track flights with an electronic data display, at five airports.
Time Based Flow Management (TBFM)	Purpose: TBFM seeks to enhance the efficiency of the NAS by using the capabilities of the existing Traffic Management Advisor (TMA) decision support tool—a tool that assigns times when aircraft destined for the same airport should cross certain points in order to reach the destination airport at a specific time and in an efficient order. FAA has already deployed the TMA at all air route traffic control centers in the contiguous United States. TBFM uses time-based metering, which creates time slots for specific fixed points along an aircraft's route that air traffic controllers can direct aircraft to cross at allotted times, to better utilize NAS capacity by improving traffic flow management of aircraft approaching and departing congested airspace and airports.
	Progress and Future Plans: FAA completed early modernization of the TMA in April 2009, and upgraded the TMA to the TBFM program in November 2014, including using metering to improve the management of traffic flow in the cruise phase of flight, increasing utilization of airspace capacity through flexible scheduling, reducing the TMA system's space requirements, and introducing NextGen concepts. FAA is currently implementing additional NextGen concepts, including providing efficient sequencing and spacing automation into terminal airspace. In fiscal year 2019, FAA plans to make a decision on whether to approve further capabilities for design, development, and implementation that would increase the benefits of time-based metering across the NAS and enable the expansion of PBN operations.

Weather	Purpose, Progress and Future Plans
Common Support Services-Weather (CSS-Wx)	Purpose: CSS-Wx will consolidate several legacy weather dissemination systems, and establish an aviation weather publishing capability for the NAS. CSS-Wx will enable integration of information from multiple weather sources and allow for better weather mitigation planning.
	Progress and Future Plans: FAA plans to begin deploying initial operating capability for the first part of CSS-Wx in January 2019 and plans to complete it in August 2020.
NextGen Weather Processor (NWP)	Purpose: NWP will provide a common weather processing platform to consolidate and replace legacy FAA weather processor systems and host new capabilities. NWP will provide a consistent weather picture, support air traffic decision-making, and consolidate multiple FAA weather programs with overlapping capabilities into a single system.
	Progress and Future Plans: FAA plans to begin deployment of initial operating capability for the first part of NWP in August 2020 and plans to complete it in August 2022. The deployment will replace and enhance the current processing and display functionality of legacy systems; generate aviation weather products with expanded coverage areas and faster update rates; generate 0-to-8 hour aviation weather products; generate safety critical alerts and real-time weather radar information; and perform translation of convective weather, such as thunderstorms, into weather constraint areas.

Source: GAO analysis of GAO and Federal Aviation Administration documents. | GAO-17-450

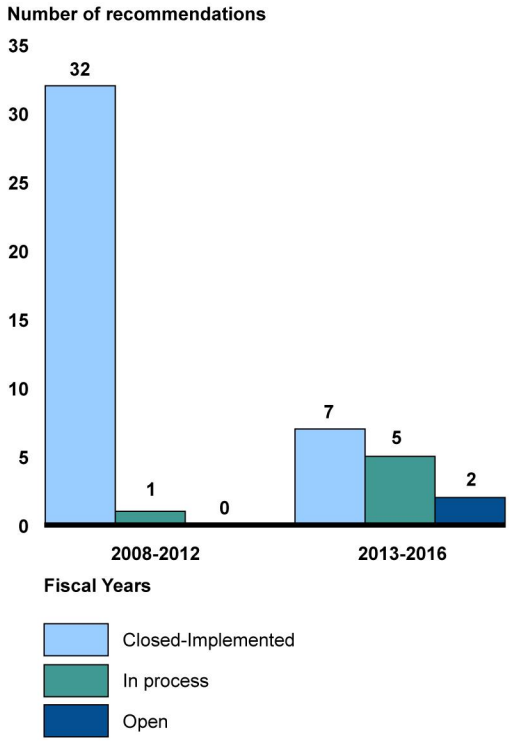
Appendix IV: Status of NextGen's Recommendations

This appendix provides an overview of the status of NextGen-related recommendations that we and the Department of Transportation (DOT) Office of Inspector General (OIG) have made to the Federal Aviation Administration (FAA) from fiscal year 2003 to fiscal year 2016.

FAA has implemented 39 of our 47 recommendations (83 percent), 6 are in process (13 percent), and 2 remain open (4 percent). Those recommendations that are "in process" include those for which FAA has provided information to GAO and asked GAO to close the recommendation as implemented. For these recommendations, the information had not been fully reviewed within GAO at the time of our review, or we had not yet determined that FAA's information sufficiently addressed our recommendation. For an overview of the status of our recommendations, see figure 6 below.[1]

[1]GAO recommendation status as of August 21, 2017. DOT OIG recommendation status as of November 17, 2016.

Figure 6: Status of GAO NextGen-Related Recommendations Made to FAA, Fiscal Years 2008–2016



Source: GAO. | GAO-17-450

[a]The status of GAO recommendations are categorized as follows: (1) open; (2) in process; (3) closed, implemented; and (4) closed, not implemented. GAO did not close any NextGen-related recommendations as "closed, not implemented" during the fiscal years 2008-2016.

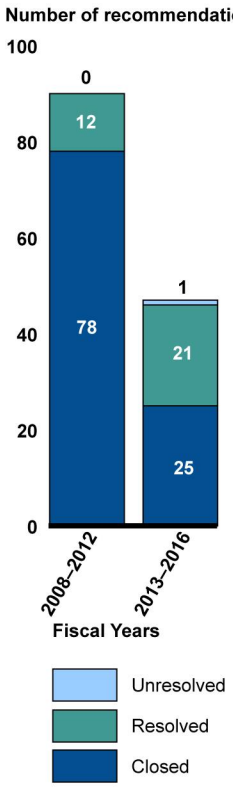
The two open recommendations are from our 2015 report on FAA's efforts to ensure the global interoperability of NextGen. In that we report, we recommended that FAA (1) conduct a risk assessment to identify potential threats to NextGen interoperability and (2) identify and document actions FAA will take to mitigate these risks.

Additionally, DOT OIG has closed 103 of the 137 recommendations (75 percent) that we determined to be related to NextGen.[2] Of the 34 DOT OIG recommendations that remain open, 33 have been resolved, meaning DOT gave OIG a target action date and concurred or partially

[2]DOT OIG closes a recommendation after the Department of Transportation has agreed with the recommendation, has taken appropriate corrective action, and has provided DOT OIG with sufficient supporting evidence to demonstrate that the action was taken.

concurred with the recommendation, while 1 remains unresolved. For an overview of DOT OIG recommendations, see figure 7.

Figure 7: Status of Department of Transportation Office of Inspector General's NextGen Recommendations Made to FAA, Fiscal Years (FY) 2008–2016



Source: GAO review of Department of Transportation Office of Inspector General documents. | GAO-17-450

[a]The status of DOT OIG recommendations are categorized as follows: (1) unresolved; (2) resolved; and (3) closed. "Resolved" means that DOT gave OIG a target action date and concurred or partially concurred with the recommendation. "Closed" means that DOT has agreed with the recommendation, has taken appropriate corrective action, and has provided OIG with sufficient supporting evidence to demonstrate that the action was taken.

Appendix V: Next Generation Air Transportation System's (NextGen) Activities Deferred Until After 2030

FAA has identified six NextGen activities that it had previously planned to complete by 2025, but has now deferred until after 2030 due to technical or operational infeasibility or changed operational needs. FAA officials explained that these applications are not in progress, and may be continually deferred, redefined, or never implemented. The following table provides an overview of these deferred activities and reasons FAA gave for deferring them.

Table 6: Next Generation Air Transportation System's (NextGen) Activities Deferred Until After 2030

Activity	Description	FAA's Reason for Deferment
High Altitude Exclusionary Airspace	The Federal Aviation Administration (FAA) envisioned a high altitude airspace in which pilots might exchange information about trajectory or trajectory intent with air traffic control to provide airspace users with more efficient route options.	Current traffic and user equipage forecasts made the concept not warranted or feasible, and Performance-Based Navigation provided similar benefits.
Future NextGen Facilities	FAA envisioned the reduction in the overall number of air traffic control facilities and gain additional benefits from NextGen (e.g. to support Big Airspace concept below), including accommodating NextGen capabilities that provide expanded services, improved flexibility and service continuity.	Due to fiscal constraints, this program was refocused on replacing the aging New York Terminal Radar Approach Control facility with a new facility at a new location.
Dynamic Airspace	As proposed by FAA, Dynamic Airspace would develop the requirements and algorithms for tools to enable air traffic managers to move airspace boundaries to match the overall level of activity in the facility's airspace and dynamically manage capacity constraints as needed.	Originally envisioned to address short term capacity constraints, Dynamic Airspace requires extensive automation support, along with trajectory information, surveillance, weather, communication, and controller display information. It was not found to be cost-beneficial at current traffic levels.
Big Airspace	FAA envisioned Big Airspace as a way to provide an integrated approach to arrival and departure management throughout major Metroplex areas by incorporating terminal and transition airspace procedures into one service volume.	Although Big Airspace could bring benefits, it was deemed too costly and difficult to achieve, due to reasons such as airspace redesign cost and complexity, extensive automation changes, NextGen facility costs, and staffing challenges.

Activity	Description	FAA's Reason for Deferment
Staffed NextGen Tower for Large Air Traffic Control Towers	FAA envisioned the concept of providing tower services for several airports at a centralized location without the traditional "out the window" view.	Research determined that technical and political obstacles were too great to deploy this concept at large air traffic control towers. According to FAA officials, FAA is supporting two state-sponsored initiatives (in Virginia and Colorado) for applying a remote tower service concept for small airports.
Automated Conflict Resolution	FAA envisioned this activity as a way to enable air traffic controllers to manage more aircraft based on pilot-preferred flight trajectories while maintaining safety.	Increased use of performance-based navigation routes in favor of user-defined routes reduced the need for Automated Conflict Resolution; the amount of software code that would be required for the capability was found to be unaffordable; and improving the en route trajectory modeler to the required accuracy proved too costly.

Source: GAO review of GAO and Federal Aviation Administration documents. | GAO-17-450

Appendix VI: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the individual named above, John W. Shumann (Assistant Director); Raymond Griffith (Analyst-in-Charge); Melissa Bodeau; Andrew Burton; Tobias Gillett; David Hooper; SaraAnn Moessbauer; Malika Rice; and Michelle Weathers made key contributions to this report.

Appendix VII: Accessible Data

Data Tables

Highlights Figure: Expected Improvements under the Next Generation Air Transportation System		
Flight planning	Integrated flight planning	Allows immediate access to identical weather information through one data source.
Push back / Taxi / Takeoff	Surface traffic management and operations	Data Communications expedite clearances and reduce communication errors. Automation reduces taxi times and enhances safety.
	Streamlined departure management	Allows multiple departure paths from each runway, thereby increasing departure capacity.
Domestic/oceanic cruise	Efficient cruise	Reduced separation standards and consideration of weather conditions allow aircraft to fly most optimal path.
Descent / Final approach / Landing	Streamlined arrival management	Equipped aircraft fly precise paths at reduced power from descent point to final approach. Time, fuel, emissions and holding are reduced.
	Enhanced surface traffic management	Detailed taxi route information sent via data communications to pilots prior to approach. Pilot and controller workload reduced and safety improved.

Source: GAO analysis of FAA information. | GAO-17-450

Figure 1: Improvements to Phases of Flight Expected under the Next Generation Air Transportation System

Flight planning	Integrated flight planning	Allows immediate access to identical weather information through one data source.
Push back / Taxi / Takeoff	Enhanced surface traffic operations	Data communications expedite clearances and reduce communication errors.
	Surface traffic management	Automation optimizes taxi routing by reducing taxi times and enhancing safety.
	Streamlined departure management	Allows multiple departure paths from each runway, thereby increasing departure capacity.
Domestic/oceanic cruise	Efficient cruise	Reduced separation standards and consideration of weather conditions allow aircraft to fly most optimal path.
Descent / Final approach / Landing	Streamlined arrival management	Equipped aircraft fly precise paths at reduced power from descent point to final approach. Time, fuel, emissions and holding are reduced.
	Enhanced surface traffic management	Detailed taxi route information sent via data communications to pilots prior to approach. Pilot and controller workload reduced and safety improved.

Source: GAO analysis of FAA information. | GAO-17-450

Figure 3: Federal Funds the Federal Aviation Administration (FAA) Has Received for Next Generation Air Transportation System (NextGen) Programs and Activities, Fiscal Years 2007 through 2016

Fiscal Year	Nominal
2007	$127,600
2008	$212,200
2009	$695,225
2010	$867,707

2011	$883,276
2012	$934,945
2013	$855,428
2014	$891,337
2015	$877,517
2016	$993082

Figure 4: The Federal Aviation Administration's (FAA) Annual Unmanned Aircraft Systems Sightings, 2014 through 2016

Year	2014	2015	2016
UAS sightings	233	1,218	1,837

Figure 6: Status of GAO NextGen-Related Recommendations Made to FAA, Fiscal Years 2008–2016

Fiscal Years	Open	In process	Closed-Implemented
2008-2012	32	1	0
2013-2016	7	5	2

Figure 7: Status of Department of Transportation Office of Inspector General's NextGen Recommendations Made to FAA, Fiscal Years (FY) 2008–2016

Fiscal Years (FY)	Closed	Resolved	Unresolved
FY 2008-2012	78	12	0
FY 2013-2016	25	21	1

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