United States Government Accountability Office

Report to Congressional Requesters

July 2015

NEXT GENERATION AIR TRANSPORTATION SYSTEM

Improved Risk Analysis Could Strengthen FAA's Global Interoperability Efforts

Accessible Version

GAO-15-608

July 2015

NEXT GENERATION AIR TRANSPORTATION SYSTEM

Improved Risk Analysis Could Strengthen FAA's Global Interoperability Efforts

GAO Highlights

Highlights of GAO-15-608, a report to congressional requesters.

Why GAO Did This Study

The United States, Europe, and other countries across the world are modernizing their ATM systems. As these efforts proceed, international coordination in developing interoperable ATM systems and procedures will be necessary to support a global aviation network and ensure the seamless transition of aircraft and aviation information across national borders.

GAO was asked to review FAA's actions to achieve the interoperability of NextGen with other countries' ATM modernization efforts. This report examines (1) selected stakeholders' views on factors that might affect NextGen's global interoperability; (2) the extent to which FAA has established a strategy to effectively achieve NextGen's global interoperability; and (3) actions FAA has taken to coordinate with other countries on global interoperability. GAO reviewed documents pertaining to FAA's international strategy and collaborative efforts with foreign and domestic aviation stakeholders. GAO also interviewed FAA officials and 25 stakeholders representing different facets of the aviation industry including foreign ANSPs, manufacturers, and standards-making bodies.

What GAO Recommends

GAO recommends that FAA conduct a comprehensive assessment of risks to NextGen's global interoperability and identify how this information will be used to mitigate risks and prioritize resources. In responding to a draft of the report, FAA agreed with the recommendations and discussed some of its ongoing risk assessment activities.

View GAO-15-608. For more information, contact Gerald Dillingham at (202) 512-2834 or dillinghamg@gao.gov

What GAO Found

Aviation industry stakeholders GAO interviewed described various factors that may affect the interoperability of the Next Generation Air Transportation System (NextGen)—a complex, long-term initiative to modernize the U.S. air-traffic management (ATM) system—with other countries' ATM modernization efforts. Interoperability allows different ATM systems and procedures to accept and use each other's information and services for technical or operational purposes. One factor described by 17 of 25 stakeholders that could affect achieving global interoperability, which, in turn, can affect NextGen's interoperability efforts, is the ability of key stakeholders, particularly air navigation service providers (ANSP) from different countries, to agree on the desired outcome of ATM modernization efforts. Stakeholders also identified several conditions that could affect when international standards are developed and when nations can implement ATM modernization efforts. For example, government and industry resource constraints could delay countries' modernization efforts and thereby could delay the interoperability of NextGen with other systems.

The Federal Aviation Administration (FAA) developed an international strategic plan in 2014 to guide internal efforts for coordinating and executing NextGen's global interoperability and other international activities. This plan and other supporting documents demonstrate, to varying degrees, five of the six characteristics of an effective strategy that GAO has previously identified. For example, FAA identified organizational roles, responsibilities, and coordination mechanisms and is developing activities and performance measures to achieve global interoperability. However, FAA lacks a mechanism for comprehensively identifying and assessing risks and for prioritizing resources to manage NextGen's interoperability risks, such as those resulting from the factors identified by aviation industry stakeholders GAO interviewed. According to FAA officials, potential risks to NextGen's interoperability are identified and assessed through working groups; however, FAA has not conducted a comprehensive risk assessment or analysis of threats and vulnerabilities specific to NextGen interoperability. Without a more comprehensive approach to assessing and managing risks, FAA is not well positioned to ensure that its strategy effectively mitigates all potential risks to NextGen's interoperability or to prioritize resources toward actions that will manage and mitigate those risks.

In addition to internal coordination efforts, FAA coordinates with the European Union and other foreign ANSPs on the global interoperability of their ATM modernization efforts through various mechanisms, such as through bilateral agreements and participation in regional and international working group forums. This coordination has resulted in efforts that further global interoperability, including agreement on a framework for developing global technology standards and conducting a demonstration of worldwide flight-information sharing. For example, FAA and European Union officials continue to collaborate to support the International Civil Aviation Organization's efforts to update the Aviation System Block Upgrades, which are designed to be consistently applied by countries and regions around the world to help achieve interoperability.

Contents

Tables

Figures

Abbreviations

ADS-B	Automatic Dependent Surveillance-Broadcast
ANSP	air navigation service provider
ATM	air-traffic management
ATN	Aeronautical Telecommunications Network
block upgrades	Aviation System Block Upgrades
CAAS	Civil Aviation Authority of Singapore
CANSO	Civil Air Navigation Services Organization
CARATS	Collaborative Actions for Renovation of Air Traffic Control System
EASA	European Aviation Safety Agency
ERAM	En Route Automation Modernization
EU	European Union
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FIANS	Future India Air Navigation Systems
GANP	Global Air Navigation Plan
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
MOC	memorandum of cooperation
NextGen	Next Generation Air Transportation System
NRC	National Research Council
RTCA	Radio Technical Commission for Aeronautics
SESAR	Single European Sky Air Transportation Management Research
SIRUS	Sirus Project
SJU	SESAR Joint Undertaking
SWIM	System Wide Information Management
WAAS	Wide Area Augmentation System

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

July 29, 2015

The Honorable Bill Nelson
Ranking Member
Committee on Commerce, Science, and Transportation
United States Senate

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

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

The Federal Aviation Administration (FAA) is leading the development of the Next Generation Air Transportation System (NextGen), a complex, long-term initiative that is to transform from 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. Europe is working on a similar transformation effort known as the “Single European Sky Air Transportation Management Research (SESAR) programme.” Outside of the United States and Europe, air navigation service providers (ANSP) in other countries such as Japan,

China, and Australia are also modernizing their air-traffic management (ATM) systems.[1]

As modernization efforts proceed worldwide, collaboration—both within FAA and with domestic and international aviation stakeholders—will be critical to developing modernized ATM 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.[2] In 2011, we found that FAA and the European Union (EU)[3] were working collaboratively toward ensuring interoperability[4] between NextGen and SESAR.[5] Since 2011, other initiatives and efforts have been undertaken to achieve global interoperability. For example, the International Civil Aviation Organization (ICAO) launched the Aviation System Block Upgrades ("block upgrades")—a framework to ensure

[1]ANSPs in other countries handle the day-to-day operations of the air-traffic control systems, while the governments regulate these activities. These ANSPs employ the workforce, maintain the infrastructure, and undertake modernization efforts. International ANSPs vary in the extent of government ownership and commercialization, with some as state-owned corporations, some as public-private partnerships, and some as private corporations. GAO, *Air Traffic Control: Characteristics and Performance of Selected International Air Navigation Service Providers and Lessons Learned from Their Commercialization*, GAO-05-769 (Washington, D.C.: July 29, 2005).

[2]The term procedures refer to the routes flown by aircraft and the rules governing those routes, such as required speeds and altitudes.

[3]For the purposes of our report, we refer to SESAR as the European Union's (EU) modernization initiative because the SESAR Joint Undertaking (SJU) was created under European Union law.

[4]For the purposes of our report, we define interoperability as the capability of two or more air-traffic management systems and procedures to accept and use information and services from each other for technical or operational purposes, enabling them to operate effectively together. Global interoperability makes air-traffic management systems and procedures compatible all over the world, allowing the seamless transition of aircraft and aviation information across national borders. Harmonization is the agreement on and implementation of compatible standards, procedures, and technologies (and associated policy) to ensure interoperability.

[5]GAO, *Next Generation Air Transportation: Collaborative Efforts with European Union Generally Mirror Effective Practices, but Near-Term Challenges Could Delay Implementation*, GAO-12-48 (Washington, D.C.: Nov. 3, 2011).

global interoperability.[6] In addition, in February 2014, FAA announced four priority initiatives for the next 4 years. One of these initiatives—the Global Leadership Initiative—aims to enhance FAA's global leadership by shaping global standards and enhancing collaboration and global harmonization to improve safety, air traffic efficiency, and environmental sustainability worldwide. This initiative entails, among other things, increasing FAA's coordination and collaboration with international partners to ensure NextGen's global interoperability.[7] As FAA transitions from planning to implementing NextGen, the agency's global leadership will be important to help achieve harmonization of standards, technologies and procedures across international boundaries.

You asked us to review FAA's actions to achieve NextGen global interoperability. We examined:

1. factors selected stakeholders identified that might affect the global interoperability of NextGen;
2. the extent to which FAA has established a strategy for achieving global interoperability of NextGen that includes key characteristics of effective strategies; and
3. actions FAA has taken to coordinate with the EU and other countries on global interoperability and outcomes stakeholders identified from these actions.

To obtain stakeholders' perspectives on factors that might affect the global interoperability of NextGen, we interviewed FAA officials and a non-probability sample of 25 aviation stakeholders, including EU officials and representatives from: ANSPs, airlines, labor unions, professional associations, manufacturers and service providers, research and development organizations, and aviation standards-making bodies such as ICAO. To obtain a diverse set of views, we selected 20 stakeholders

[6]ICAO is the international body of the United Nations that, among other things, promulgates international standards and recommended practices in an effort to harmonize global aviation standards. The United States has agreed to and is required to comply with ICAO standards or notify ICAO of differences and publish them in the U.S Aeronautical Information Publication.

[7]Broadly, the other three initiatives are to: (1) make aviation safer and smarter using risk-based decision making; (2) deliver benefits through technology and infrastructure, including improvements being implemented as part of NextGen; and (3) develop FAA's workforce.

from across these categories, based on our knowledge of the aviation industry and selected 5 additional stakeholders based on recommendations we received from interviewees. To assess FAA's strategy for ensuring global interoperability of NextGen, we evaluated the strategy—as outlined in various FAA plans and supporting documents—against key characteristics we have previously identified as effective characteristics of a national strategy.[8] We also interviewed FAA officials about the contents of its strategy and progress it has made in implementing it. To examine actions FAA has taken to coordinate with the EU and other countries on global interoperability and outcomes —both foreign and domestic— resulting from these actions, we reviewed documentation from FAA and its international counterparts.[9] We also assessed FAA's collaborative efforts with the EU against effective collaborative practices we have previously identified.[10] We also interviewed FAA officials, officials from the EU, ANSPs, research and development organizations, and aviation standards-making bodies to obtain perspectives on FAA's collaborative efforts. See appendix I for a more detailed description of our scope and methodology and for a complete list of all the stakeholders we interviewed.

We conducted this performance audit from September 2014 to July 2015, 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

[8]GAO, *Combating Terrorism: Evaluation of Selected Characteristics in National Strategies Related to Terrorism*, GAO-04-408T (Washington, D.C.: Feb. 3, 2004). The characteristics were developed in consultation with a variety of public and private sources, such as literature on strategic planning and performance, and prior GAO reports.

[9]These counterparts include the European Union, Nav Canada, the Civil Aviation Authority of Singapore, Air Services Australia, and the Civil Aviation Bureau of the Ministry of Transport of Japan.

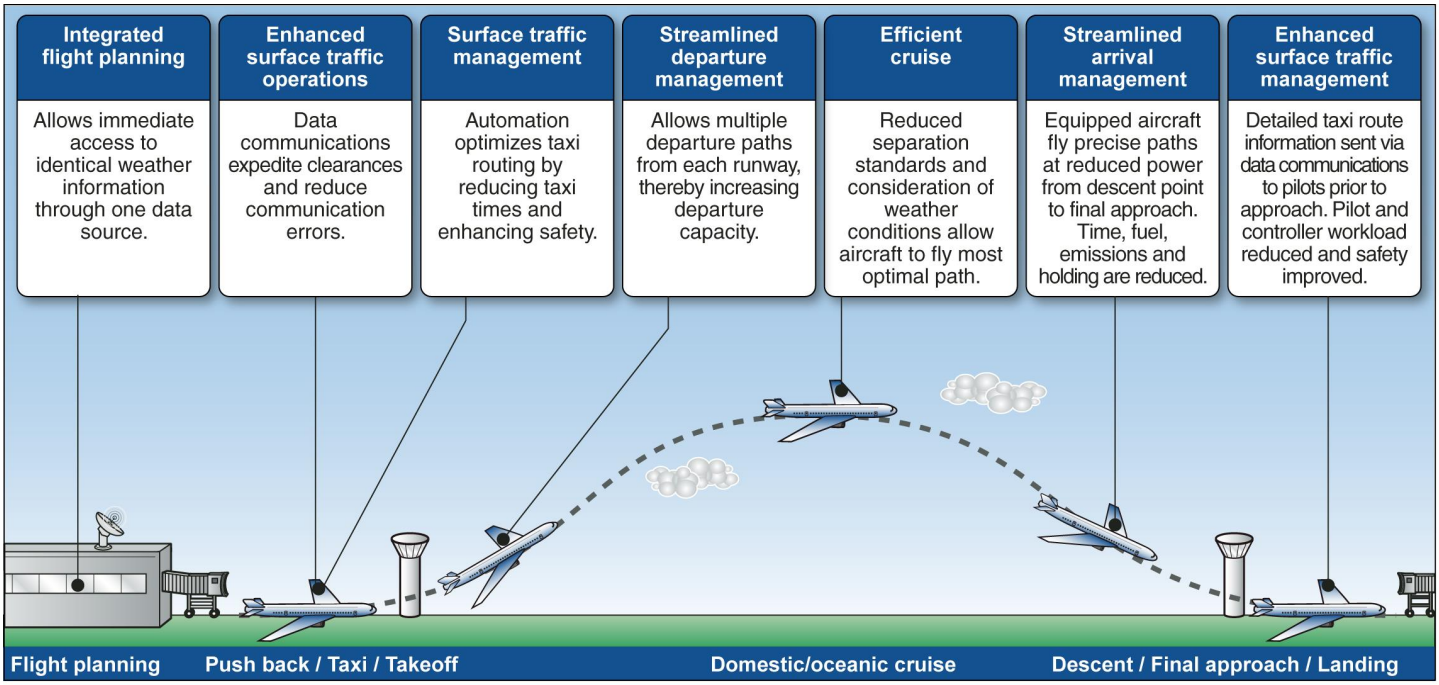
[10]GAO, *Results-Oriented Government: Practices That Can Help Enhance and Sustain Collaboration among Federal Agencies,* GAO-06-15, (Washington, D.C.: Oct. 21, 2005). In addition, GAO published recent reports that expand on the collaborative criteria discussed in GAO-06-15. Those reports include GAO, *Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanisms,* GAO-12-1022 (Washington, D.C.: Sept. 27, 2012) and GAO, *Managing for Results: Implementation Approaches Used to Enhance Collaboration in Interagency Groups,* GAO-14-220 (Washington, D.C.: Feb. 14, 2014).

the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

While several countries are implementing numerous ATM improvements, FAA's NextGen and the EU's SESAR are the two largest airspace modernization projects currently under way. Both systems envision an airspace system in which network-based information and automation optimize an aircraft's operations in all phases of flight—from flight planning at the start to landing and taxiing to the gate at the end—to reduce flight delays and maximize airspace capacity while reducing aircrafts' environmental impacts and fuel consumption. See figure 1 for an illustration of how NextGen is envisioned to work.

Figure 1: Flight Profile in the Next Generation Air Transportation System (NextGen) Environment Envisioned by the Federal Aviation Administration (FAA)



Source: GAO analysis of FAA information. | GAO-15-608

Several NextGen capabilities related to communications, navigation, and surveillance are being developed and implemented and will require international coordination to ensure harmonized standards, technologies, and procedures are developed. Examples of these capabilities, as planned by FAA, include the following:

- *Performance-based navigation:* Navigation procedures are to be based on the performance capabilities of an aircraft, meaning that equipped aircraft and flight crews are to be able to select their own flight paths, within defined limits, and use satellites in addition to existing ground-based aids for navigation.
- *Data Communications (Data Comm):* Data Comm would supplement existing voice communications between pilots and air traffic controllers. For example, pre-scripted e-mail-like messages would replace routine voice communications between air traffic controllers and pilots. Data Comm would also enable ground systems to communicate directly with aircraft flight-management systems. This communication is to also enable complex route instructions and procedures to be quickly loaded upon acceptance by the pilot, resulting in a more direct exchange of information.
- *Automatic Dependent Surveillance-Broadcast (ADS-B):* A satellite-based system known as ADS-B is to first augment ground-based radar and then gradually replace it as a primary mode of tracking aircraft location.
- *System Wide Information Management (SWIM):* SWIM infrastructure is to connect various networks within and among ANSPs and provide all aviation users—pilots, air traffic controllers, and aircraft dispatchers—with the same aviation-related information. Such information is to include current weather or flight planning information that would allow aircraft dispatchers and air traffic controllers to collaborate on the routing and rerouting of traffic based on real-time information.

Like NextGen, SESAR is a large scale modernization effort and is intended to develop common aviation technologies for use across Europe. Several key differences between FAA's and EU's governing structures contribute to differing management of NextGen and SESAR. For example, whereas FAA manages the airspace for the United States, the EU has 28 sovereign member states with their individual regulators and service providers. In implementing SESAR, EU officials must consider interoperability among its member states. In addition, while FAA has the primary responsibility for developing, managing the transition to, and implementing NextGen, the SESAR program is structured in three phases, each of which has been managed by a different organization. For example, an industry consortium acting under a framework contract co-

financed by the European Commission[11] and EUROCONTROL[12], an intergovernmental organization made up of 41 member states and the EU, managed the definition phase (2006 to 2008). The SESAR Joint Undertaking which is made up of the European Commission, EUROCONTROL, and 15 member organizations—including airport operators, ANSPs, ground and aerospace equipment manufacturers, and aircraft manufacturers—is managing the development phase (2008 to 2016). In December 2014, the SESAR Deployment Alliance was named as manager of the deployment phase (ongoing to 2025) of SESAR.[13]

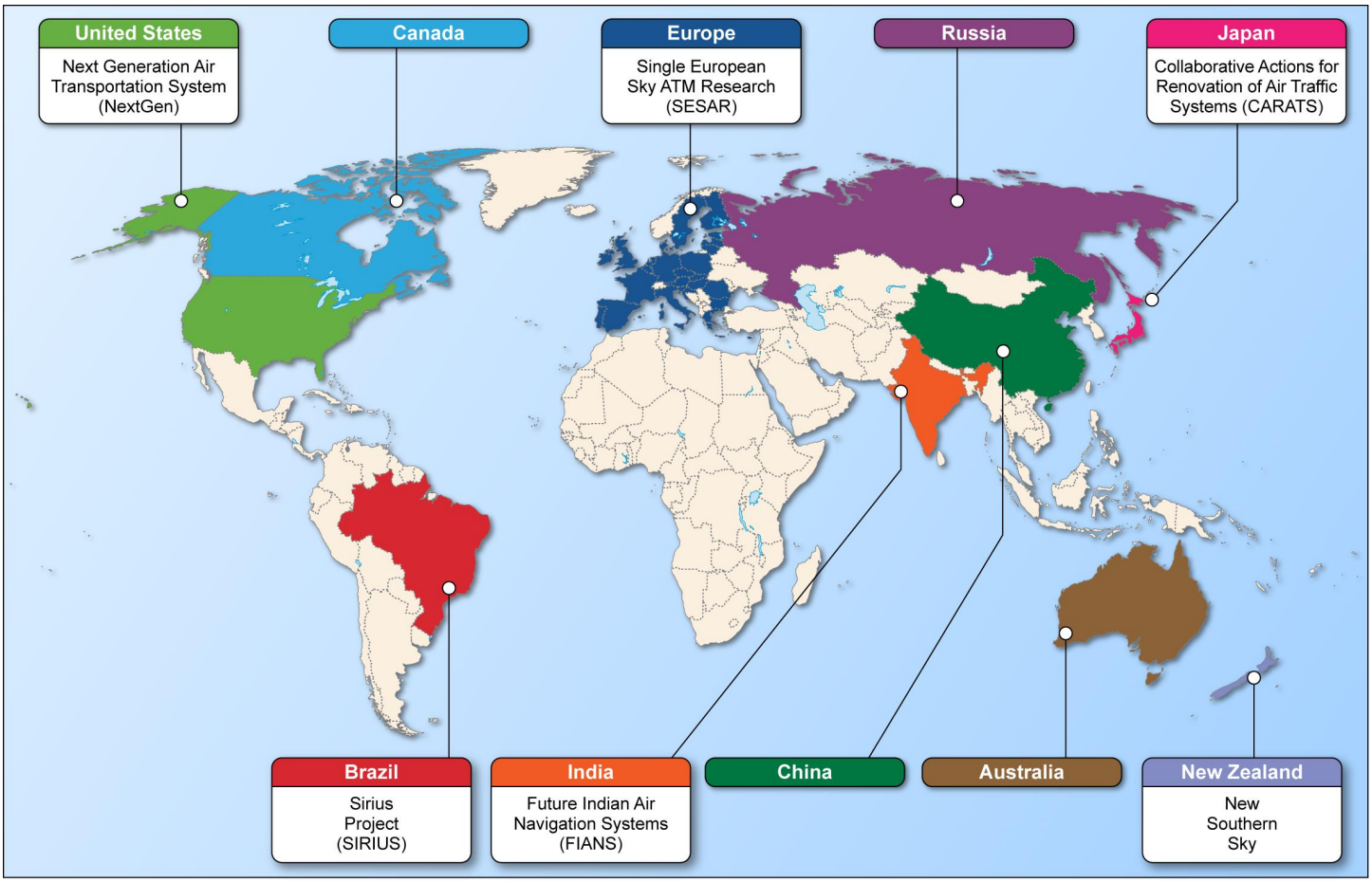
Modernization efforts outside of the United States and EU vary in scope and size and are in different stages of development and implementation (see fig. 2 for examples of air-traffic management modernization programs worldwide). For example, Japan is in the process of implementing the Collaborative Actions for Renovation of Air Traffic Control System (CARATS), a large-scale transformational system similar to NextGen and SESAR, that is scheduled to be implemented from 2011—2025. In contrast, other foreign ANSPs are taking a more incremental approach when deploying new technologies and in some cases, are purchasing commercial "off-the-shelf" technologies.

[11]The European Commission is the executive body of the European Union, representing the interests of the EU as a whole. It proposes legislation for the European Parliament and the Council of Ministers to adopt, implements common policies, and manages the EU's budget and programs. It is the signatory authority on collaborative agreements with FAA and oversees SESAR's management.

[12]EUROCONTROL aims to achieve safe, efficient, and environmentally friendly air traffic operations across the European region and provides technical expertise for building the Single European Sky—an initiative to reform European ATM and reduce the fragmentation of air navigation services in Europe. EUROCONTROL's 41 member states includes all of the 28 European Union member states and an additional 13 member states. During the definition phase the European Commission and EUROCONTROL coordinated—through a contract with a 30-member consortium of airlines, air navigation service providers, airports, manufacturers, and others—to produce the European Air Traffic Management Master Plan.

[13]The SESAR Deployment Alliance consists of a group of ANSPs, airports, and airlines that are to oversee SESAR deployment.

Figure 2: Examples of Air-Traffic Management (ATM) Modernization Programs Worldwide



Source: GAO. | GAO-15-608

Note: Australia, Canada, China, and Russia have modernization programs underway, but do not have umbrella names for these programs.

As all of these efforts proceed, global interoperability will be necessary for the seamless transition of aircraft and aviation information across national borders. A single approach may not be applicable to all countries or regions because there is wide variation among countries with regard to levels of traffic density, traffic complexity, and ATM infrastructure. Therefore, ATM systems do not need to be identical in order to be interoperable—i.e., systems and aircraft can accept and use information and services from each other for technical or operational purposes, enabling them to operate effectively together. To ensure interoperability, standards-making bodies establish guidelines or requirements for air-traffic management systems and then ANSPs come to agreement on and

implement compatible standards, procedures and technologies. Interoperability and harmonization can be achieved among neighboring countries, regions, or globally.

A variety of aviation organizations and stakeholders are involved in developing global standards to help achieve regional and global interoperability of air-traffic management systems, including ANSPs, regulators, manufacturers, and operators. This coordination occurs in various venues including the Radio Technical Commission for Aeronautics (RTCA)[14], the European Organization for Civil Aviation Equipment (EUROCAE)[15] and ICAO. RTCA and EUROCAE formed, jointly led, and staffed special committees to develop standards specifically for new technologies that NextGen and SESAR are to employ and to help ensure interoperability in technologies that may differ in some ways between the two systems.

ICAO serves as a forum for international cooperation on setting global standards and recommended practices necessary for aviation safety, security, efficiency, and environmental protection. This work is accomplished in air navigation meetings, working groups, and technical panels, with participation from ANSPs and aviation experts from around the world. In addition to developing standards, ICAO released in 2013 the Global Air Navigation Plan (GANP) and block upgrades. The GANP and block upgrades together serve as the framework and road map for developing global standards and achieving global harmonization of ATM systems. The block upgrades describe operational performance improvements, organized into flexible and scalable building "blocks." Each "block" includes a set of unique modules that are linked to one of four aviation performance improvement areas (see fig. 3).[16] Each module defines a single capability (technology or procedure) and identifies the

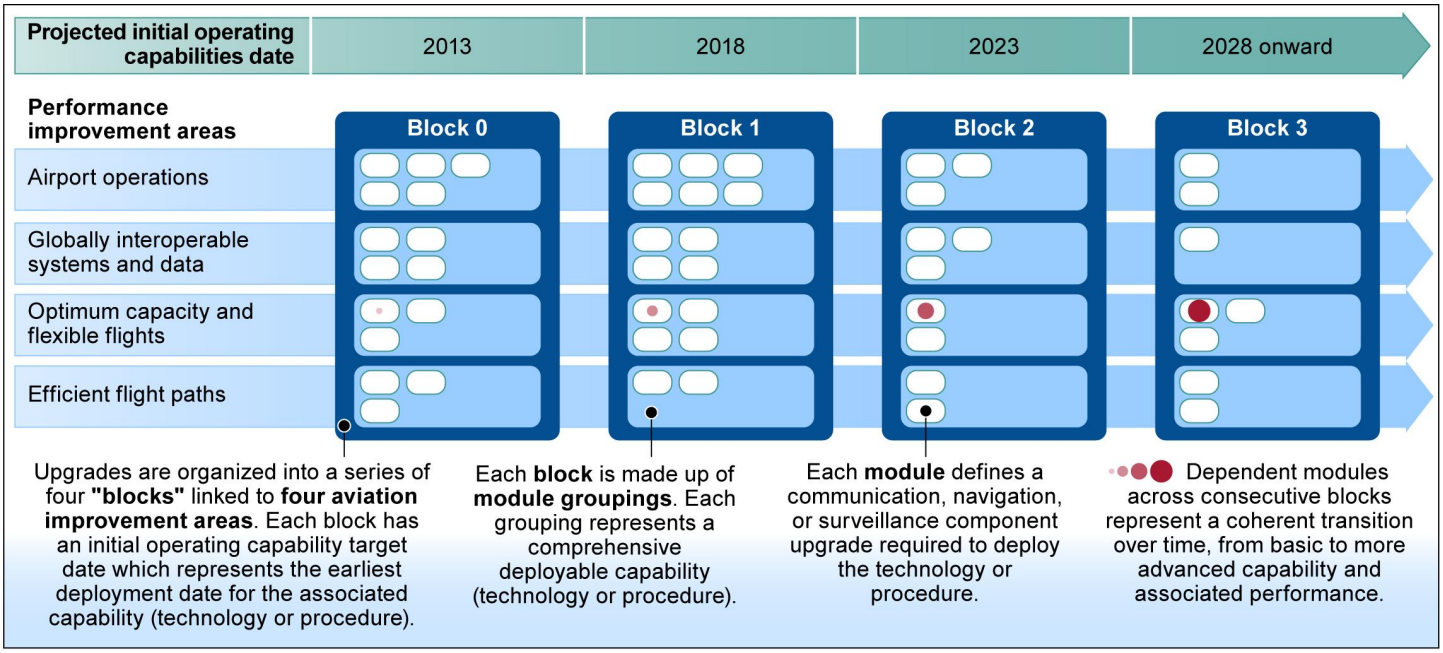
[14]RTCA, which includes representatives from industry and FAA, is a private non-profit U.S based organization that develops consensus based performance standards for air-traffic control systems. It serves as an advisory body to FAA whose recommendations are the basis for a number of FAA's policy, program, and regulatory decisions.

[15]EUROCAE is a non-profit organization dedicated to developing aviation standards in the EU. The organization is composed of members, which specialize in technical fields of aeronautics.

[16]The four performance improvement areas include: (1) airport operations; (2) globally interoperable systems and data; (3) optimum capacity and flexible flights; and (4) efficient flight path.

required technology, timelines for implementing the technology, and procedures to implement that capability—collectively identified within roadmaps. Each individual country or region can implement the blocks as needed, based on its own determination of needs and resources. The blocks are organized in 5-year increments for each of the four aviation-performance improvement areas, beginning with Block 0, with projected dates for when the standards and regulations are in place to support the implementation of the capabilities. Block 0, for example, identifies capabilities that were available for ANSPs and operators to begin implementing in 2013 for each performance improvement area.

Figure 3: International Civil Aviation Organization's (ICAO) Aviation System Block Upgrades



Source: International Civil Aviation Organization (ICAO). | GAO-15-608

Note: The ICAO block upgrades (blue columns) refer to the target timelines for a group of capabilities (technologies and procedures) that will enable global interoperability in each of the four aviation performance improvement areas. The number of modules in a given block or aviation performance improvement area can vary.

The block upgrades are designed to be consistently applied by countries, regions, or sub-regions around the world to help achieve harmonization and interoperability. According to FAA officials, the agency was a key contributor to the development of the block upgrades and as such, the block upgrades largely reflect existing capabilities in NextGen.

According to Stakeholders, NextGen Global Interoperability May Be Affected by the Ability to Reach Agreement on and Timing of International ATM Modernization

The 25 stakeholders whom we interviewed represented different facets of the aviation industry and identified numerous factors that may affect NextGen global interoperability. We grouped these factors into two categories—factors that affect (1) the ability of international aviation stakeholders (e.g., ANSPs and industry) to reach agreement on ATM modernization and (2) the timing of international standards-development and implementation of ATM modernization.

Ability to Reach Agreement on ATM Modernization

Almost all (24 of the 25) stakeholders we interviewed described the ability of international aviation stakeholders to reach agreement on proposed ATM modernization capabilities as a factor that may affect NextGen's global interoperability. Stakeholders provided a number of conditions that affect ability to reach agreement. We grouped them into three categories: 1) political conditions; 2) ability of ANSPs to agree about the desired outcome of ATM modernization; and 3) industry views regarding the perceived costs and benefits of ATM modernization.

- **Political conditions:** Twelve stakeholders described political conditions and issues related to national sovereignty that may present challenges to building support for, and agreement on proposed ATM modernization capabilities, challenges that, in turn, could affect global interoperability, including NextGen interoperability. For example, one stakeholder described national politics as a barrier to building consensus for a collaborative ATM system in the Middle East region. The region has numerous airports in different countries, and according to the stakeholder, consensus will be necessary to reap the benefits of advanced modernized ATM systems. In addition, the EU's ATM modernization is challenged by issues pertaining to national sovereignty, such as nations wishing to retain control over their airspace, according to two stakeholders. ATM modernization efforts in Europe require coordination across 28 different ANSPs, each of which has different models and systems and in some cases may not want to

cede authority over them.[17] National sovereignty not only complicates agreement on ATM modernization within Europe, but also affects agreement on what ATM capabilities are needed. For example, one stakeholder noted the difficulty of building a SWIM network to connect Europe's 28 different ANSPs to enable information sharing, compared to the simpler task of developing SWIM in the United States, which connects multiple systems with FAA, a single agency.

- **Ability of ANSPs to agree on the desired outcome:** Seventeen stakeholders described the ability of ANSPs to agree on the desired outcome of ATM modernization efforts as an example of a factor that may affect global interoperability which, in turn, could affect NextGen interoperability. For example, in 2013 the European Industry Consultation Body reported to the European Commission that the number one risk to the SESAR ATM modernization program was lack of agreement on vision and goals.[18] In particular, according to one stakeholder, the European Commission is having difficulty finding common ground among the European ANSPs' positions regarding ADS-B, with some ANSPs "pushing back" on implementation of ground infrastructure. However, for ATM modernization efforts that require interoperability, European ANSPs need to be in agreement on the desired outcome for there to be agreement—and ultimately, interoperability—between the United States and Europe.

  Five stakeholders we spoke with noted that different nations or regions may not be able to reach consensus because they need different solutions, and the choice of solution may affect global interoperability. For example, one aviation manufacturer we spoke with said that the type of SWIM infrastructure a country elects to implement may restrict the capability for information sharing. As we previously discussed, SWIM infrastructure would connect various networks and manage aviation-related information so that all aviation users have the same information. If the networks are consolidated, similar to FAA's SWIM design, aviation information consumers—domestically and internationally—can freely access data within the system. The free exchange of information may enable countries to

[17]According to ICAO, each state has sovereignty over the airspace above its territory, but may delegate functional responsibilities, such as provision of air navigation services.

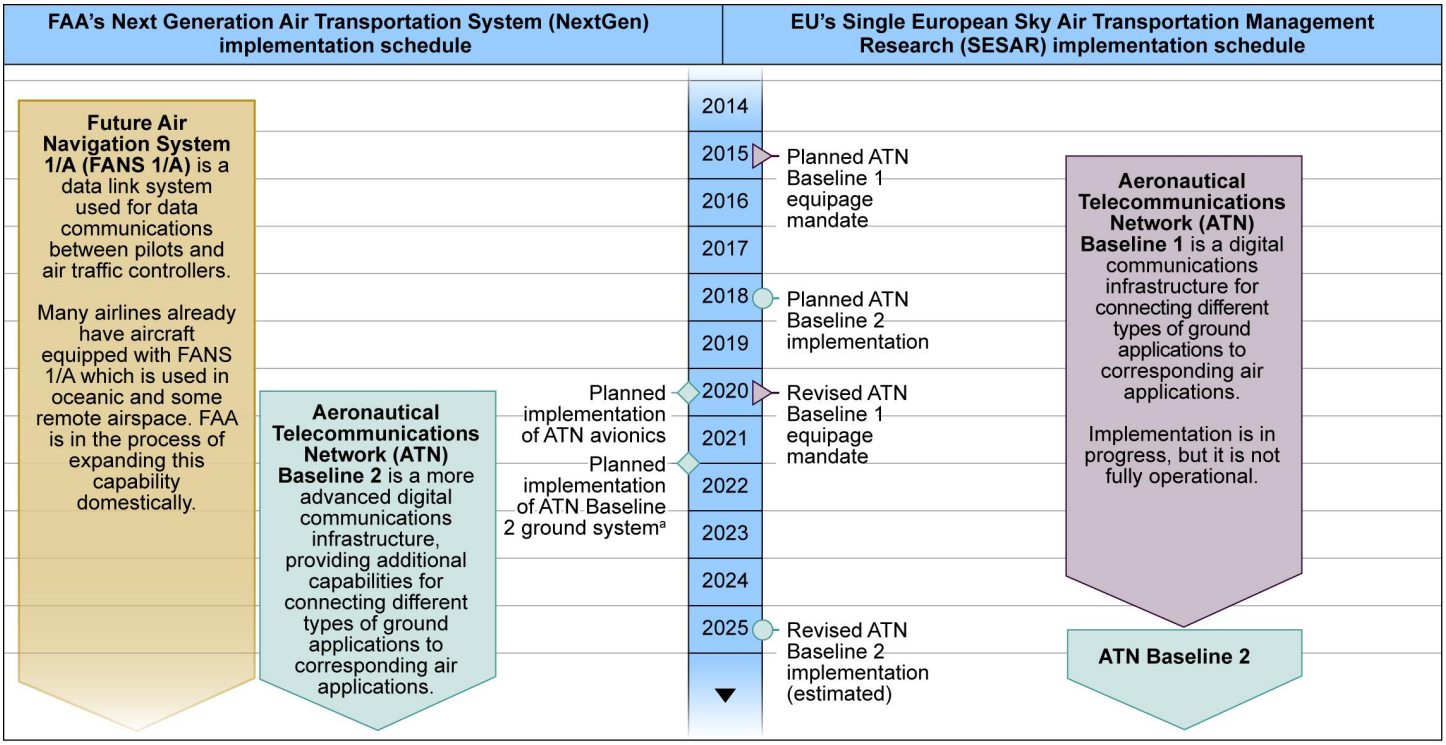
[18]See Industry Consultation Body, *Shaping the ICB work programme: SES Top 10 Risks* (December 2013). The Industry Consultation Body provides technical advice to the European Commission on the implementation of SESAR.

fully leverage the benefits of SWIM. Conversely, if the networks are federated such that each ANSP retains autonomy, information producers may limit access to consumers and inhibit innovation, according to the manufacturer we interviewed. The manufacturer noted that reduced access and innovation in turn would limit the benefits of SWIM—both to the modernizing ANSP and the aviation system globally, but as long as implementation uses globally recognized SWIM standards, then global interoperability will be facilitated.

Even when different nations or regions reach consensus on a desired outcome, they can take different implementation approaches to achieve that outcome. For example, Data Comm is one capability that many stakeholders described as in need of harmonization. As shown in figure 4, the FAA and EU agreed on a plan to deploy the Aeronautical Telecommunications Network (ATN) Baseline 2 capability for Data Comm by 2025. The EU is beginning to roll out ATN Baseline 1 first, with a mandate for airlines to equip by 2020, followed by plans to implement ATN Baseline 2.[19] On the other hand, FAA is using the Future Air Navigation System 1/A (FANS 1/A) for its first phase of Data Comm capability enhancements and plans to deploy ATN Baseline 2 by 2021/2022. According to FAA officials, FAA decided to not implement ATN Baseline 1 because aircraft operating in both North America and Europe are already equipped with FANS 1/A avionics for oceanic operations and FANS 1/A offers re-route capabilities that the EU's ATN Baseline 1 does not. According to airline representatives we spoke to, the two approaches could require work-arounds for some aircraft operating in both environments, such as double-equipping aircraft or applying for exemptions, which may reduce benefits from Data Comm capabilities. EU officials that we spoke to stated that in the interim, aircraft that are only equipped with FANS 1/A will still be able to operate in European airspace but with more limited capabilities. However, EU officials noted that it will be important that by 2025 airlines operating in both the United States and Europe are equipped with ATN Baseline 2 to achieve benefits, and FAA and the EU will have to work together to develop standards for these future improvements.

[19]Originally, the EU planned to implement ATN Baseline 2 in 2018, but since the EU has delayed its ATN Baseline 1 mandate to 2020, it has revised plans for implementing ATN Baseline 2. According to FAA and one aviation stakeholder, Europe is unlikely to begin implementation of ATN Baseline 2 until approximately 2025.

Figure 4: Data Communications Implementation Schedule for the Federal Aviation Administration (FAA) and the European Union (EU), 2014 to beyond 2025



Source: GAO. | GAO-15-608

Note A: According to FAA officials, the estimated date for FAA's planned implementation of ATN Baseline 2 ground system is 2021 or 2022.

Disagreement about the desired outcome of capabilities may result in different standards or practices being adopted in different countries. Five stakeholders described the potential effects that may result from standards that are higher in one country than in other countries, or exemptions in one nation but not in others. According to stakeholders, these differences can pose potential safety risks and can result (1) in difficulties in deciding when and what product to equip aircraft with and (2) in the necessity of developing specialized products and services for different ANSPs and the aircraft that operate within their airspace. For example, for ADS-B, at the time FAA issued the final rule mandating a performance standard for equipping aircraft, the standard[20] could only be met using a Wide Area Augmentation

[20]75 Fed. Reg. 30160 (May 28, 2010).

System (WAAS) Global Positioning System (GPS) receiver. According to FAA, this equipment will augment information sent to GPS receivers to enhance the accuracy and reliability of position estimates when aircraft use satellite navigation. However, the WAAS GPS receiver is not required to meet ADS-B performance standards in Europe or Australia. Two airline stakeholders expressed concern that this difference may lead to different or additional equipage for aircraft flying to the U.S. than to other countries, but according to FAA officials, recent data has shown that under the current GPS satellite configuration, the FAA performance standard set in 2010 can be met without the WAAS GPS receiver.[21]

One stakeholder also told us that establishing a common set of technological and operational road maps in sufficient detail to avoid regional divergence is difficult to accomplish. In the stakeholder's view, without an agreed-upon road map for ATM modernization, regions will implement technologies or procedures that are not interoperable and create operational challenges to reaching the desired benefits. ICAO's aviation—system block upgrades were developed to help mitigate regional divergence and to identify operational and technological requirements that would need to be harmonized regionally and globally. However, one stakeholder told us that the block upgrades define operational requirements at a very high level and as a result, several different technologies can be used to support the same operational requirement, a situation that can affect interoperability efforts.

- **Industry views regarding the perceived financial benefits and costs of ATM modernization:** Thirteen stakeholders described conditions in which the aviation industry may have different views than ANSPs and aviation regulators on the associated financial benefits and costs of ATM modernization efforts, views that may affect their stance on a given standard, technology, or procedure. These differences may pose challenges for industry and other aviation stakeholders to reach agreement on ATM modernization-implementation plans, a result that, in turn, could affect NextGen interoperability. Four airline stakeholders and one manufacturing stakeholder described the importance of costs and benefits of ATM modernization on industry decisions, and how this presents a different perspective from that of regulators on issues such as route

[21]FAA analyzed data collected from January 12, 2015 through March 30, 2015.

efficiencies.[22] Two of these stakeholders recalled previous modernization efforts in which airlines equipped aircraft with capabilities that were not used because either ANSPs decided not to pursue the capability or aircraft were retired before the capability was operational. As we have previously found, airlines and others are unlikely to invest in equipment without greater certainty of when and where implementation of ATM modernization will occur.[23] This uncertainty can be a challenge because, as one stakeholder noted, time frames for making decisions about purchasing and upgrading planes are significantly shorter than the time frames for developing and implementing ATM modernization.

In addition, six stakeholders we spoke with emphasized the importance of harmonizing standards and stated that harmonized standards help to minimize the financial impact of the development and implementation of new capabilities on the aviation industry. According to three stakeholders, unharmonized standards lead to additional costs for aviation manufacturers in two ways—the need to develop multiple solutions, with fewer potential customers for each, and the need to double- or triple-equip aircraft. In addition, when harmonized standards enable universal solutions, manufacturers and vendors can market one solution to different regions and operators do not have to implement multiple sets of procedures or technologies, according to two stakeholders.

Timing of Standards-Development and Implementation of ATM Modernization Efforts

Almost all of the stakeholders (23 of 25) described the timing of standards-development and implementation of ATM modernization efforts across the globe as factors that may affect the timing of global interoperability of NextGen. Seven stakeholders noted the importance of timing—both regionally and globally—and said that planning, setting

[22]For example, benefits from performance-based navigation include route efficiencies (i.e. shorter flight paths and reduced aircraft fuel burned) and reduced noise in surrounding communities. FAA has made trade-offs between route modernization efforts that yield some benefits and can be implemented quickly and those that could result in greater benefits but would take much longer to implement. According to FAA officials, some of the proposed changes would benefit a particular procedure or operator, but they may not fit within the air-traffic control structure without wholesale airspace redesign. GAO, *NextGen Air Transportation System: FAA Has Made Some Progress in Midterm Implementation, but Ongoing Challenges Limit Expected Benefits*, GAO-13-264, (Washington D.C.: Apr. 8, 2013).

[23]GAO-13-264.

standards, and establishing strategies cannot produce outcomes from a capability that requires interoperability if others in the region are not implementing this capability at the same time. As we previously stated, cost and benefit uncertainty can inhibit industry stakeholders' willingness to equip. The stakeholders identified conditions that could affect the timing of standards-development and implementation including: 1) different starting points for each nation's ATM modernization efforts; 2) a lengthy process for establishing harmonized standards, technologies, and procedures; 3) a lengthy process for implementing standards, technologies, and procedures; and 4) resource and finance constraints.

- **Different starting points:** Fourteen stakeholders emphasized that differences among nations' characteristics, procedures, and definitions can affect each country's starting point, pace, and time needed to complete different ATM modernization efforts. For example, when airlines fly to certain regions of Africa, pilots must use navigation methods that were last used in the United States in the 1930s because, as we previously found, airspace in some regions of Africa is not controlled by air navigation systems.[24] The Civil Air Navigation Services Organization (CANSO) has been working with African states to implement ICAO's block upgrades to help address the lack of infrastructure and air navigation services in remote areas in Africa.[25] In addition, phraseology used for communications in different countries' airspace, and developing universal definitions can be a challenge, according to one stakeholder.[26]

  Also, according to six stakeholders, a country's geographic size, population, and existing infrastructure can affect how quickly a country can modernize its ATM system. For example, according to two stakeholders, although ADS-B research and development started in

[24]GAO, *International Aviation: Federal Efforts Help Address Safety Challenges in Africa, but Could Benefit from Reassessment and Better Coordination*, GAO-09-498 (Washington, D.C.: June 16, 2009).

[25]The lack of such technology increases the potential for midair collisions, affecting both civilian and military aviation, but airlines have developed ways to mitigate risk. According to one airline stakeholder, airlines specifically train for differences in procedures to mitigate potential safety threats. An African airline previously said that it reduces risk of collisions by flying to certain regions only during daytime hours. GAO-09-498

[26]Some countries may specify phraseology that is different from ICAO standards and recommended practices, so pilots refer to each country's Aeronautical Information Publication for the correct phraseology to use in that country's airspace.

the United States, ANSPs in Australia and Canada were able to implement ADS-B more quickly than FAA due to various factors such as not having an existing legacy surveillance system to maintain and having a less complex air-traffic control system.[27] According to Air Service Australia officials, the majority of the continent was managed by air-traffic control without surveillance. Air Service Australia decided to implement ADS-B because it was the most cost effective surveillance option compared to radar. According to three stakeholders, a comparatively small country may have an opportunity to adopt ATM modernization elements faster than large countries or those with large existing legacy systems to maintain.[28] However, FAA and EU remain at the forefront of ATM modernization, according to five stakeholders. For example, one stakeholder noted that the advantage of United States and EU relations is that their aviation organizations are stable and are able to maintain continuous relationships. In addition, some nations may face technical barriers to adopting Internet-protocol-based ATM modernization because they may not have the necessary technology and infrastructure to support such capabilities, according to one stakeholder. [29]

- **Standards-development process:** Eleven stakeholders described the lengthy process of harmonizing standards, technologies, and procedures as an example of how timing can affect NextGen's global interoperability. Stakeholders' different priorities and countries' different starting points for ATM modernization may contribute to the length of the standards-development process. According to six stakeholders, developing standards at ICAO can take time, normally 2 to 5 years by one stakeholder's estimate, but once developed they are likely to be widely adopted by individual countries. However, ICAO can take longer to develop some standards than others. For example, according to one stakeholder, it took 10 years to establish an ICAO

[27]Implementation of ADS-B in Australia and Canada provided surveillance capabilities where there was no existing radar coverage, according to two stakeholders.

[28]As we have previously found, FAA will have to decommission some of its older equipment and infrastructure while at the same time implementing NextGen capabilities. GAO, *National Airspace System: Improved Budgeting Could Help FAA Better Determine Future Operations and Maintenance Priorities*, GAO-13-693 (Washington, D.C.: Aug. 22, 2013).

[29]Internet protocol, the principal communications protocol on which the Internet is based, is a networking technology that has been the industry's standard method to network computer systems since the late 1990s.

standard on airport Wi-Fi. One stakeholder noted that the work at ICAO tends to be dominated by a handful of countries—including the United States, Germany, France, England, and some others from the EU—that have the funding to send staff and the ability to effectively influence other countries and obtain agreement. According to FAA officials, they work and engage with ICAO's regional planning groups because while a lot of countries participate in ICAO discussions, not many of them do the technical work of standards development.

In addition, competition for attention and resources may lead to delays in the standards-development process. For example, one stakeholder noted that if certain staff are unable to attend a meeting, a country's input may not be considered in the standards-development discussion or standards-development can be delayed until it has the required attendance. According to FAA officials, ICAO regional offices' limited personnel and resources can affect the momentum of block upgrades implementation. In another example, a stakeholder emphasized that ensuring new technology meets safety criteria adds an additional layer of work and requires further standards development that can lead to delays in implementing a technology.

- **Implementation process:** Twenty stakeholders described the lengthy process of implementing standards, technologies, and procedures as an example of how time frames can affect the timing of NextGen global interoperability. Four stakeholders emphasized the challenge of implementing ATM modernization. ICAO has over a thousand air-navigation services standards, but according to ICAO officials, more than half of countries have implementation rates below 60 percent, in large part because of insufficient financial and human resources.[30]

  Stakeholders we interviewed cited several reasons for the length of implementation time frames. For example, without an efficient governance structure, timelines and implementation schedules can quickly get off track, according to one stakeholder. Four stakeholders expressed concerns about implementation of Data Comm, including the need for predictability to boost stakeholder confidence and ensure the availability of products from manufacturers, while one stakeholder said there are ways to work around differences in aircraft equipage

[30]The degree of a country's development is directly related to the percentage of effectively implemented ICAO standards, but there seems to be little correlation between standards implementation and the amount of air traffic or size of a country's airspace, according to ICAO officials.

and only a basic level of communication capability is necessary on each aircraft. In addition, as we previously mentioned, some countries, like the United States and EU, have complex legacy systems, which can contribute to longer implementation phases for new ATM capabilities. According to one stakeholder we spoke with, the processes to certify aviation equipment are also slow because the European Aviation Safety Agency (EASA) and FAA, which handle aviation regulations in Europe and the United States respectively, are risk-averse organizations whose missions primarily focus on safety.[31] According to EASA officials, the time needed for certification is dependent on the safety and performance that need to be assessed and the environment in which the performance would need to be evaluated.

In addition, one stakeholder expressed concern that delays in FAA's implementation of NextGen could result in other countries developing different requirements that require different equipage, different regulations, and potentially increased training requirements. Moreover, the stakeholder said that certain program delays can further delay implementation of dependent NextGen programs. As we previously found in February 2012, in the United States the interdependencies of acquisition programs have become more prominent as the NextGen program shifts from planning to implementation, so that cost increases and schedule delays in one program could have a cascading effect on other programs.[32] According to FAA officials, until the SESAR program began entering the implementation phase, there was a perception that the EU's SESAR program could implement earlier than FAA's NextGen program because of inaccurate comparisons of FAA's implementation documents—which account for the current state of the budget—with Europe's planning documents. Two stakeholders acknowledged that the EU sets more aggressive implementation time frames than FAA,

[31]In our prior work, we reported that industry stakeholders, and experts have long raised questions about the efficiency of FAA's certification and approval processes, which lead to delays that have been attributed to heavy staff workloads and a lack of staff resources to begin new work on certifications and approvals. For more information, see GAO, *Aviation Manufacturing: Status of FAA's Efforts to Improve Certification and Regulatory Consistency*, GAO-14-829T (Washington, D.C.: July 31, 2014).

[32]Due in part to delays to FAA's En Route Automation Modernization program, baselines for Data Comm and SWIM were also delayed. GAO, *Air Traffic Control Modernization: Management Challenges Associated with Program Costs and Schedules Could Hinder NextGen Implementation*, GAO-12-223 (Washington, D.C.: Feb. 16, 2012).

but one stakeholder said that the EU is quick to change an implementation timeline if it is no longer feasible.

- **Resource and finance constraints:** Twelve stakeholders stated that resource and finance constraints facing ANSPs, operators, and manufacturers can delay decision-making and implementation of ATM modernization, which can affect NextGen global interoperability. Seven stakeholders and FAA officials described the dependability and sufficiency of funding to implement ATM modernization as a challenge to interoperability.[33] For example, according to FAA officials, budget sequestration delayed the implementation schedules of some NextGen-related programs, including Data Comm, Time Based Flow Management, and the En Route Automation Modernization (ERAM) program.[34] In addition, two stakeholders told us that insufficient funds are their biggest challenge to providing free information and training about the block upgrades to ANSPs. One stakeholder noted that FAA supports a lot of standards that will be difficult for ANSPs in other countries to implement, because unlike FAA, they do not have the resources to build customized ATM modernization solutions. Instead, other countries typically buy "off-the-shelf" products that may not be able to meet a lot of the standards FAA supports, according to the stakeholder. According to FAA officials, FAA advocates for solutions that match the needs of individual countries, solutions that may differ from those FAA adopts.

  In addition, industry's perception of the financial benefits and costs of ATM modernization efforts may affect the timing of aircraft being equipped with new capabilities, as well as the ability of industry to come to agreement with ANSPs and regulators, as discussed above. ICAO officials told us that they have a multidisciplinary working group looking at how to financially incentivize airlines to equip with new technologies. Specifically, the group is considering guidance for funding or financing block upgrades. ICAO standards permit air navigation service charges (i.e., user fees or taxes) to finance ATM modernization, but do not prescribe a particular method of financing

[33]In September 2014, we found that FAA and 43 stakeholders identified budget uncertainty as a difficulty for FAA's ability to continue operation of an efficient air-traffic control system and/or implementation of NextGen. GAO, *Air Traffic Control System: Selected Stakeholders' Perspectives on Operations, Maintenance, and Structure*, GAO-14-770 (Washington D.C.: Sept. 12, 2014).

[34]Time Based Flow Management is a tool to adjust airspace capacity and demand imbalances.

for ATM modernization efforts. In addition, according to ICAO officials, the multidisciplinary working group is assessing the adequacy of ICAO's guidance on "service priority." Service priority, also known as "best equipped, best served" is the concept that aircraft with more advanced ATM capabilities would be eligible for priority air-traffic management services relative to aircraft using older technologies.[35] Incentivizing equipage and adoption of capabilities by rewarding early adopters with better service is an important element of ATM modernization, according to one stakeholder.

FAA's International Strategy Incorporates Some Elements of an Effective Strategy, but Lacks Mechanism for Assessing and Managing Risks

FAA's International Strategy Demonstrates the Six Characteristics of an Effective Strategy to Varying Degrees

As an outcome of FAA's Global Leadership Initiative, in 2014, FAA initiated several efforts to internally coordinate activities in support of its four key strategic initiatives, including harmonizing air-traffic management technologies and procedures.[36] In particular, FAA developed an international strategic plan, which, in conjunction with other supporting documents, outlines FAA's internal strategic approach for coordinating, approving, and executing FAA's international activities and efforts,

[35]In the United States, the FAA Modernization and Reform Act of 2012 requires FAA to report on options to encourage equipping aircraft with NextGen technologies, including a policy that gives priority to aircraft equipped with ADS-B technology, and the costs and benefits of each option. Pub. L. No. 112-95, § 222, 126 Stat. 11, 54 (Feb. 14, 2012). We have found that designing operational incentives and analyzing how they can work in practice would present significant challenges. See *GAO, Next Generation Air Transportation System: FAA Faces Challenges in Responding to Task Force Recommendations,* GAO-10-188T (Washington D.C.: Oct. 28, 2009) and GAO-13-693.

[36]This initiative encompasses global harmonization goals to better coordinate and collaborate on interoperability issues to ensure NextGen interoperability.

including its global harmonization activities.[37] According to FAA officials, prior to the development of the international strategic plan, different offices within FAA had their own separate international strategic plans that were not well communicated. According to FAA officials, the prior approach lacked a solidified structure to enable the agency to identify and address agency-wide priorities, optimally allocate international resources, and ensure that when different parts of the agency communicated with international entities, they articulated the same strategy and perspective.

We previously identified six characteristics an effective national strategy should include (see table 1).[38] We determined that these characteristics are equally applicable to an international strategy because the characteristics are those that we have previously found to be reflected in a wide range of different types of strategies. Inclusion of all six characteristics enhances the strategy's usefulness to policy decision makers and implementers to shape policies, programs, priorities, resource allocations, and standards. As shown in table 1, FAA's strategy for achieving global interoperability fully demonstrates inclusion of one of these characteristics, partially demonstrates inclusion of four characteristics, and does not demonstrate inclusion of the remaining characteristic.[39]

[37]For the purposes of our analysis, we evaluated FAA's international strategic plan and other supporting documents that FAA officials told us related to FAA's international strategic plan. These documents include FAA's *NextGen Implementation Plan*, FAA's fiscal year 2015 business plans, FAA's Strategic Priorities and Priority Initiatives and FAA's FY 2015 Performance Metric Scorecard.

[38]GAO, *Combating Terrorism: Evaluation of Selected Characteristics in National Strategies Related to Terrorism*, GAO-04-408T (Washington, D.C.: Feb. 3, 2004). The characteristics were developed in consultation with a variety of public and private sources, such as literature on strategic planning and performance, and prior GAO reports.

[39]We determined that a characteristic was: (1) "demonstrated" if FAA's international strategic plan or supporting documents provided support for all of the elements of a characteristic; (2) "partially demonstrated" if FAA's international strategic plan or supporting documents provided support for some but not all of the elements of a characteristics; and (3) "not demonstrated" if FAA's international strategic plan or supporting documents did not provide any support for elements of a characteristic.

Table 1: Extent to Which the Federal Aviation Administration's (FAA) International Strategy Exhibits Characteristics of an Effective National Strategy

Characteristic	Key elements of the characteristic	GAO assessment
Organizational roles responsibilities and coordination	(Overall)	**Demonstrated**
	Describes roles and responsibilities of specific federal agencies, departments, or offices.	Demonstrated
	Describes specific mechanisms or processes for coordinating or collaborating.	Demonstrated
Purpose, scope, and methodology	(Overall)	**Partially demonstrated**
	Describes the purpose of the strategy.	Demonstrated
	Describes the scope of the strategy including, major functions, mission areas, or activities the strategy is intended to cover.	Demonstrated
	Describes the methodology used to produce the strategy.	Not demonstrated
Problem definition and risk assessment	(Overall)	**Partially demonstrated**
	Describes the problems, their causes, and operating environment that the strategy is directed toward.	Demonstrated
	Describes completed risk assessment, or analysis of threats and vulnerabilities, and discusses the quality of available data. [Note A]	Not demonstrated
Goals, subordinate objectives, activities, and performance measures	(Overall)	**Partially demonstrated**
	Describes what the strategy is intended to achieve (i.e., desired outcome).	Demonstrated
	Describes specific activities to achieve goals.	Partially demonstrated
	Describes specific, outcome-related performance measures, priorities, milestones and process for monitoring progress towards achieving goals.	Partially demonstrated
Integration and implementation	(Overall)	**Partially demonstrated**
	Describes how the strategy relates to other strategies' goals, objectives and activities.	Demonstrated
	Describes how the strategy is integrated with relevant implementation documents.	Partially demonstrated
Resources, investments, and risk management	(Overall)	**Not demonstrated**
	Describes what the strategy will cost, the sources and types of resources and investments needed (i.e., budgetary, human capital, information technology, etc.).	Not demonstrated
	Describes how risk assessment (discussed above) will be used to make management decisions about resource allocations to minimize risks and maximize returns on resources expended.	Not demonstrated

Source: GAO analysis of FAA information | GAO-15-608

Note A: For this characteristic, we only assessed the extent to which FAA completed and documented a risk assessment. We did not assess the extent to which FAA evaluated the quality of available data, because the only available data that FAA can use to assess NextGen interoperability risks are existing FAA NextGen program data. Therefore this element is not applicable.

Note: We determined that a characteristic was: (1) "demonstrated" if FAA's international strategic plan or supporting documents provided support for all of the elements of a characteristic; (2) "partially demonstrated" if FAA's international strategic plan or supporting documents provided support for some but not all of the elements of a characteristics; and (3) "not demonstrated" if FAA's international strategic plan or supporting documents did not provide any support for elements of a characteristic.

Roles and Responsibilities

FAA has identified organizational roles, responsibilities and coordination mechanisms for achieving global interoperability. Specifically, FAA's

international strategic plan and fiscal year 2015 business plans describe the roles and responsibilities of FAA offices in completing interoperability activities, as well as the specific mechanisms FAA has in place for coordinating and collaborating across the agency. As we have previously found, the inclusion of this characteristic helps agencies to clarify specific roles, coordinate their efforts, and enhance accountability. FAA's international strategic plan provides a framework for FAA to identify the specific harmonization activities that will be carried out by each of FAA's lines of business. In addition, FAA's annual business plans describe the specific roles, responsibilities, and global harmonization activities of each of FAA's lines of business. In 2014, FAA also established a new governance structure under the Global Leadership Initiative—the International Advisory Board and the International Steering Committee—which serve as agency-wide governance bodies for FAA international activities going forward.[40] According to FAA officials, these bodies were established to help FAA coordinate international activities across FAA. The bodies will be responsible for, among other things, developing and overseeing the execution of the international strategic plan, setting strategic goals, applying those goals to all international activities and programs, and ensuring that they are integrated into relevant business plans to achieve annual targets.

Purpose, Scope, and Methodology

FAA articulated the purpose of establishing a strategy and the scope of its coverage but did not document the process by which it was developed. For example, FAA's international strategic plan specifies that the purpose of the strategy is to:

1. enhance FAA's ability to optimally allocate international resources to achieve U.S. objectives;
2. provide a 4-year approach for coordinating, approving, and executing FAA's international activities and efforts; and
3. describe how FAA will adapt its international engagement efforts to address global challenges and achieve United States' aviation objectives.

[40]The International Advisory Board and the International Steering Committee have representation from all of FAA's organizational components with international activities or programs. The International Advisory Board provides executive oversight and direction to the International Steering Committee.

The plan also states that the strategy is targeted to FAA activities that have an international engagement component, such as international activities that will help achieve NextGen interoperability. FAA's documents do not describe the process for producing the plan—a key characteristic of an effective strategy. A description of the process involved in producing the plan can help communicate assurance that the appropriate individuals and entities were consulted when drafting the strategy. While FAA's international strategic plan does not describe the process for producing the plan, FAA officials told us that the plan was developed by the International Steering Committee along with input from the International Advisory Board, the FAA Administrator and FAA executive management.

Problem Definition and Risk Assessment

FAA describes in its international strategic plan several different international challenges that the strategy is intended to address, such as challenges associated with achieving global interoperability. However, FAA has not conducted a comprehensive risk assessment or analysis of threats and vulnerabilities specific to NextGen interoperability. For example, FAA's international strategic plan includes a high-level problem definition of the global trends and associated international engagement challenges affecting global interoperability. It states that divergent global standards and practices result in a need for FAA to work with international stakeholders to effectively harmonize standards and recommend practices. However, FAA has not identified or assessed whether or how these or other factors might affect NextGen interoperability. As discussed earlier in this report, stakeholders we spoke with identified several different factors that might affect the interoperability of NextGen, such as resource and finance constraints and the timing of implementation of ATM modernization efforts. These factors could pose risks to and affect the outcome of NextGen interoperability efforts. In our work on characteristics of an effective strategy, we found that comprehensive assessments of vulnerabilities, including risk assessments, can help identify key factors both internal and external to an organization that can significantly affect that organization's attainment of its goals. A risk assessment can also aid in the identification of priority goals, objectives, and activities.

According to FAA officials, potential NextGen interoperability risks generally arise through working groups and panel discussions. As discussed later in this report, FAA participates in several working groups and panels that are tasked with helping to develop standards. FAA officials told us that some of the topics that may be discussed during these meetings include ATM modernization efforts being undertaken in other countries, potential areas where implementation plans may not

align, and potential impacts of ATM modernization efforts on stakeholders, such as impacts to air carrier operations. However, according to FAA officials, FAA has not completed a comprehensive risk assessment to identify potential threats or vulnerabilities to NextGen interoperability. In addition, FAA does not have a mechanism for:

- comprehensively identifying or tracking interoperability risks to NextGen programs on a routine basis,
- evaluating potential consequences across its programs, and
- identifying potential impacts on global interoperability efforts.

According to FAA officials, the agency's existing processes, including the outcomes from the various work groups, demonstrate that the agency is identifying and addressing potential risk. However, according to GAO's *Standards for Internal Control in the Federal Government*, a comprehensive risk assessment entails identifying risks throughout the entity, considering different types of risks that might affect the entity, assessing the likelihood of those risks and incorporating an analysis of those identified risks to provide a basis for managing and responding to the risks.[41]

An analysis of risks could aid FAA in identifying potential impacts to interrelated NextGen programs and NextGen interoperability efforts. For example, according to one foreign ANSP we spoke to, delays in ERAM's implementation had an impact on the ability of that ANSP's air-traffic system to exchange data with the U.S.[42] Similar interdependencies may exist between NextGen programs and modernization efforts in other

[41]GAO, *Standards for Internal Control in the Federal Government*, AIMD-00-21.3.1, (Washington D.C.: Nov. 1, 1999). Revised standards will be effective beginning with fiscal year 2016. See GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: September 2014).

[42]As we previously found in February, 2012 insufficient stakeholder involvement contributed to delays to FAA's En Route Automation Modernization, which in turn forced FAA to delay Data Comm and SWIM milestones. In addition, as the NextGen program shifts from planning to implementation, interdependencies have become more prominent, so that cost increases and schedule delays in one program could have a cascading effect on other programs. We recommended that FAA should, among other things, require cost and schedule risk analysis, independent cost estimates, and integrated master schedules to better estimate the cost and completion dates for major acquisitions. FAA is taking steps to implement this recommendation. GAO-12-223.

countries—both for developing harmonized standards, technologies, and procedures and for implementation. In addition, in the absence of a comprehensive risk assessment, FAA does not have a mechanism for assessing potential risk mitigation options. FAA's lack of an approach for identifying and assessing potential risks makes it more challenging for FAA to develop a strategic approach for mitigating risks. In addition, a recent report from the National Research Council (NRC) stated that FAA has not clearly articulated or qualified in order of importance, the risks to NextGen which in turn makes it difficult for FAA to make sound decisions about how to prioritize efforts and allocate resources.[43] The NRC further stated that for a large-scale, critical initiative such as NextGen, clear assessments, understanding, and communication of risks are essential.

Goals, Subordinate Objectives, Activities, and Performance Measures

FAA identified overall goals and subordinate objectives for achieving global interoperability, but has not yet fully identified specific activities it plans to undertake to achieve these goals or developed a process for tracking and monitoring progress in achieving these goals. Specifically, FAA identified several overarching goals for ensuring NextGen interoperability in the agency's international strategic plan, such as: (1) ensuring seamless international airspace boundaries; (2) developing harmonized standards for ATM technologies; and (3) ensuring FAA and U.S. industry standards, technologies, and procedures are accessible to the global aviation market. In addition, FAA has started identifying some activities that will help support achievement of these goals but has not yet fully identified activities that align to each of the NextGen interoperability goals described in the FAA's international strategic plan. According to FAA officials, beginning in fiscal year 2016, each FAA office will be required to develop an annual work plan that describes the international activities that each FAA office intends to undertake to achieve the NextGen interoperability goals described in the international strategic plan. FAA plans to consolidate its work plans into one FAA-wide international work plan that provides a consolidated look at all the international activities that each of the FAA offices is completing. These individual office work plans will be used track and monitor progress in achieving these goals. Officials also noted that the International Steering Committee and the International Advisory Board will use the office work plans to prioritize resources and investments and will develop

[43]National Research Council, *A Review of the Next Generation Air Transportation System: Implications and Importance of System Architecture*, Washington D.C., 2015.

performance measures to track and monitor progress in achieving interoperability goals.

Integration and Implementation

FAA's international strategic plan describes how the plan is aligned with other FAA initiatives, such as the goals of FAA's Global Leadership Initiative and other strategic activities that FAA is undertaking. In addition, FAA is in the process of aligning specific line of business working level activities to its international strategic plan. Specifically, FAA offices are developing work plans for fiscal year 2016 that will describe international activities FAA plans to undertake to achieve the NextGen interoperability goals described in FAA's international strategic plan. Linking these work plans to the international strategic plan will better enable FAA to articulate a complete vision of the agency's overall NextGen interoperability efforts to stakeholders, a linkage that some industry stakeholders we spoke to felt was lacking. For example, representatives from one aviation manufacturer told us that they believe FAA lacks a strategic approach to addressing global interoperability issues and that because FAA has been so internally focused on implementing NextGen they have not developed an international strategy to blend FAA efforts with what is happening in other countries. Another stakeholder told us that until recently, FAA had not communicated to entities outside of FAA its vision, strategy, or approach to achieving global interoperability. This stakeholder told us that while FAA's leadership has been working hard over the past couple years to develop a strategy and approach for facilitating coordination across its business units to carry out FAA's global interoperability activities, FAA has much more work to do to ensure FAA initiatives are coordinated and prioritized and that activities being undertaken by FAA offices are aligned.

Resources, Investments, and Risk Management

FAA has not identified the costs, sources, and types of resources and investments needed to implement the activities that will support the NextGen interoperability goals described in its strategy, or how FAA intends to prioritize, allocate, and manage resources and investments to achieve these goals. In particular, the international strategic plan and associated documents do not describe how FAA will prioritize activities to support the plan's interoperability goals based on assessments of the risks and relative to the costs of mitigating them. According to FAA officials, FAA is in the progress of identifying the associated costs, sources, and types of resources and investments to allocate to specific NextGen interoperability activities. As previously discussed, each of the FAA lines of business is developing a work plan that summarizes activities each office plans to undertake. FAA officials explained that a key role of the International Advisory Board will be to examine the

individual office work plans for 2016 which in turn will help FAA identify areas that need to be prioritized or need additional resources.

While these work plans may help FAA determine how much funding is going towards specific areas and whether resources need to be reallocated to a different area, as previously discussed, FAA has not, nor does it plan to, conduct a comprehensive risk assessment that would help determine risk areas and prioritize the allocation of resources accordingly. According to FAA officials, the work that they undertake at the working group level is sufficient for identifying risks and determining what activities need to be prioritized. We have previously found that inclusion of risk management principles could aid implementing parties in prioritizing and allocating resources to balance risk reductions and costs.[44] Such an analysis would better enable FAA to allocate resources toward activities that mitigate risks and maximize results. Because FAA has not comprehensively identified and assessed the risks associated with its NextGen interoperability activities, it is not well positioned to prioritize activities to address these risks, identify the relative costs of mitigating the risks, and direct resources accordingly. By incorporating information from risk assessments in its decision making, FAA could better position itself to minimize risks and maximize returns on resources expended on activities that link to FAA's interoperability goals. Specifically, incorporating information from risk assessments could help FAA prioritize: 1) collaboration with foreign ANSPs; 2) expenditure of resources on technical and operational support to foreign ANSPs; and 3) coordination with standards-making bodies, on the development of global standards and procedures, which are global interoperability activities that FAA is currently engaged in and which are discussed further later in this report.

[44]GAO-04-408T.

FAA Coordinates with International Partners through Various Mechanisms, Resulting in Decisions Furthering Interoperability

In addition to developing a structure to guide its internal coordination efforts, FAA coordinates with international partners, such as EU officials and ANSPs in other countries, on global interoperability efforts. This coordination occurs through (1) bilateral agreements with individual countries; (2) participation in regional and international working group forums; and (3) sharing best practices through technical assistance, training, and other programs. These efforts have resulted in some decisions and outcomes to further global interoperability, such as agreement on standard development, operational improvements to be included in ICAO's Global Air Navigation Plan and block upgrades, and efforts to accelerate development and implementation of new technologies, capabilities, and procedures. Stakeholders that we spoke to provided different perspectives on the effectiveness and usefulness of these collaborative efforts.

Bilateral agreements

As we found in 2011, the 2011 memorandum of cooperation (MOC) between FAA and the EU has supported effective collaboration on NextGen and SESAR interoperability.[45] Specifically, we found that through this agreement, FAA and the EU shared a common goal, developed a strategy for working together, defined roles and responsibilities, leveraged resources, identified a process for monitoring and evaluating their coordination efforts; and reinforced individual accountability for collaborative efforts through agency performance management systems. [46]

Our review of FAA's collaborative efforts with the EU since 2011 shows that FAA continues to implement effective collaborative practices,

[45]GAO-12-48.

[46]As previously discussed, we reviewed FAA and EU collaboration efforts in 2011 and found that these efforts generally mirrored six of the seven effective collaborative practices that we have observed in successful interagency collaborations. These practices include (1) defining and articulating a common outcome; (2) establishing mutually reinforcing or joint strategies to achieve the outcome and establishing compatible policies, procedures, and other means to operate across agency boundaries; (3) agreeing upon respective roles and responsibilities; (4) identifying and addressing needs by leveraging resources; (5) developing mechanisms to monitor, evaluate, and report the results of collaborative efforts, (6) reinforcing individual accountability for collaborative efforts through agency performance management systems; and (7) reinforcing agency accountability for collaborative efforts through agency plans and reports. See GAO-12-48 and GAO-06-15. In addition, GAO published recent reports that expand on the collaborative criteria discussed in GAO-06-15. See GAO-12-1022 and GAO-14-220.

including addressing one practice we had previously found FAA was not demonstrating. Specifically, FAA improved communication of its collaborative efforts with the EU through its plans and reports to better inform aviation stakeholders of its efforts and to improve accountability for, and the credibility of, these efforts, as we recommended in 2011. FAA has reported information about its harmonization activities in its annual NextGen Implementation Plans, as well as in the annual business plans of FAA's Air Traffic Organization. FAA and the EU also released a joint report in December 2014 summarizing FAA and EU progress towards achieving interoperability between NextGen and SESAR based on the cooperative activities identified in the MOC.[47] This report is available on FAA's website and will be updated on a biannual basis, according to FAA officials. In addition, starting in early fiscal year 2014, FAA initiated joint NextGen and SESAR briefings to stakeholders at the NextGen Advisory Committee on the status of EU collaboration.[48] These briefings are conducted by executives from NextGen and SESAR and are intended to provide ongoing updates on NextGen and SESAR harmonization activities. According to FAA officials, FAA and the EU plan to continue to hold these briefings at the future NextGen Advisory Committee meetings. In addition, in June 2015, FAA and EU signed a letter of intent to expand the 2011 MOC to include collaboration on the deployment and implementation of NextGen and SESAR, ongoing research on the interoperability of airport avionics, and operational and communication protocols and procedures under NextGen and SESAR.

FAA also has bilateral agreements with ANSPs in other countries that cover a range of topics including issues that promote NextGen and future interoperability of aviation systems in other regions and to support the development and implementation of new ATM procedures and improvements. See table 2 for examples of some of these agreements. For example, in September 2013, FAA and the Civil Aviation Authority of Singapore (CAAS) signed a memorandum of cooperation to coordinate on, among other things, research and development activities to advance ATM modernization efforts.

[47]FAA, and the Office of the European Union, *NextGen and SESAR State of Harmonisation Document*, December 2014.

[48]The NextGen Advisory Committee is comprised of aviation stakeholders from the government and industry. The committee's primary focus is on implementation issues, including prioritization criteria at a national level, joint investment priorities, and location and timing of capability implementation.

Table 2: Examples of Bilateral Agreements that the Federal Aviation Administration (FAA) Has in Place with Air Navigation Service Providers in Other Countries

Air Navigation Service Provider	Description of agreement
Air Services Australia	Technical assistance agreement *(annex 3 signed 2009)* between FAA and Air Services Australia to collaborate on developing aeronautical-information management concepts, architecture and systems and developing joint policies, and systems and concept of operations that are in compliance with the International Civil Aviation Organization (ICAO) standards and recommended practices. The agreement includes a work plan with specific harmonization activities to be completed from 2009 to 2013.
Civil Aviation Authority of Singapore, Air Navigation Services Group	Memorandum of cooperation *(signed 2013)* to share information regarding programs and projects, execution of joint analysis, coordination of research and development programs and projects to advance air-traffic management modernization and other activities.
Civil Aviation Bureau of the Ministry of Transport of Japan	Memorandum of cooperation *(signed 2006)* with Japan's Civil Aviation Bureau of the Ministry of Transport to establish a joint working group to meet twice a year for the purpose of identifying areas of mutual interest, exchanging information, developing recommendations on project areas that will advance harmonization of Japan's Collaborative Actions for Renovation of Air Traffic Control System (CARATS) and FAA's Next Generation Air Transportation System (NextGen), and presenting these recommendations to other entities for consideration, implementation or execution.
Nav Canada	Cooperative agreement *(signed 1997)* to coordinate on issues related to providing and developing air navigation services, including but not limited to, the functional areas of communications, navigation, surveillance, and air-traffic management. FAA and Nav Canada also signed a declaration of intent *(signed 2013)* to cooperate on, among other things, developing common requirements, policies, standards and operational procedures for space based Automatic Dependent Surveillance-Broadcast (ADS-B) surveillance and incorporation of space-based ADS-B into oceanic and remote airspace controlled by FAA and Nav Canada.

Source: GAO analysis of FAA documents. | GAO-15-608

Note: The type of agreement that FAA has with an ANSP can vary and depend on whether the ANSP is a private entity or a government entity.

According to FAA officials, the collaborative work that has been accomplished between FAA and other ANSPs under the bilateral agreements has resulted in several decisions that further global interoperability. For example, a recent outcome from FAA and EU collaboration has been the development of an agreed-upon NextGen and SESAR Joint Avionics Roadmap. This roadmap identifies and provides timelines for development of aircraft capabilities for navigation, surveillance, and data communications. In addition, much of the collaborative work done under the bilateral agreement directly supports standards-development decisions. According to FAA, the bilateral agreements have provided a mechanism for the agency to work through disagreements on ATM capabilities with its foreign counterparts. Stakeholders we interviewed provided different perspectives on the effectiveness and usefulness of bilateral agreements with other countries.

For example, some stakeholders (8 of 25) viewed bilateral agreements between FAA and ANSPs in other countries as a useful mechanism for collaborating on shared priorities and for helping to develop global standards.

Officials whom we interviewed from the EU and from two of the three ANSPs stated that having existing bilateral agreements with FAA was essential. For example, officials from two ANSPs we interviewed stated that bilateral agreements can also help expedite the process of developing global standards. According to one ANSP, if two countries see common alignment, they can work together to develop a proposal for a standard and then present that approach at ICAO to convince other countries or regions to adopt that standard. This process can, in turn, help expedite the ICAO standards-making process, which as we discussed earlier, some stakeholders stated can be lengthy. Another stakeholder, however, cautioned that when standards advocated in bilateral discussions occur outside of the ICAO process, it can complicate efforts to harmonize standards at ICAO. According to this stakeholder, this approach can affect the ability of representatives from the rest of the world to advocate solutions other than those pursued by FAA and the EU.

Working Group Forums

Outside of formal agreements, FAA collaborates with officials from other countries through committees led by standards-making bodies and international working groups. For example, FAA and the EU coordinate through the jointly led and staffed RTCA and EUROCAE special committees.[49] RTCA and EUROCAE have formed 13 joint special committees to develop standards for the new technology that NextGen and SESAR will employ and help ensure interoperability in technologies that may differ in some ways between the two systems. For example, Special Committee 214 was formed to develop guidance material to define the safety, performance, and interoperability requirements for air traffic services supported by data communications. Similar joint special committees are addressing topics that several stakeholders we

[49]RTCA is a private, not-for-profit corporation that develops consensus-based performance standards for air-traffic control systems. It serves as a federal advisory committee whose recommendations are the basis for a number of FAA's policy, program, and regulatory decisions. RTCA's membership includes both domestic and international organizations representing different sectors of the air transportation industry. EUROCAE develops technical standards for European aviation systems in collaboration with international organizations and United States counterparts.

interviewed identified as being important interoperability issues, including standards related to ADS-B and SWIM. According to FAA officials, the most significant work to help ensure interoperability occurs in these special committees. Several industry stakeholders we spoke to stated that these committees are important for addressing interoperability issues. One airline representative stated that although differences in technical standards arise, RTCA and EUROCAE have provided the venue to coordinate on issues that help to eliminate or minimize challenges arising from those differences.

FAA also coordinates with other countries through participation in ICAO's standards-development working groups and other ICAO efforts. For example, FAA has been an active participant on ICAO panels to develop standards in the areas of trajectory management, which provides additional reliability regarding an aircraft path and increases the overall predictability of aviation systems. FAA and the EU have recently agreed to support ICAO's Information Management Panel to develop harmonized standards on trajectory management issues. In addition, the FAA and EU collaborated to provide support to the development of ICAO's Global Air Navigation Plan and block upgrades. Specifically, FAA and the EU provided ICAO with a list of NextGen priorities and inventories of the standards necessary to support implementation of the block upgrades. These inventories were used by ICAO to develop a prioritized list of required ICAO standards and to help prioritize workloads. According to FAA officials, FAA will continue to support ICAO in developing the next edition of the Global Air Navigation Plan and block upgrades, which will be released in 2016 to further decision making to achieve global interoperability. According to ICAO estimates, more than 50 percent of ICAO's 191 member countries have mapped their current ATM improvement programs to the ICAO block upgrades. ICAO officials told us that this number includes countries with significant air traffic growth such as China, India, and Brazil.

Stakeholders we spoke to were generally supportive of the block upgrades. For example, twelve stakeholders we spoke to described the block upgrades as a success and helpful to achieve global interoperability. One industry manufacturer stated that ANSPs outside of the United States and Europe look to ICAO to help them guide decision making. According to this industry manufacturer, having the block upgrades framework is helpful to achieving NextGen interoperability because as industry representatives communicate with various ANSPs all over the world, they can explain how a technology fits into that framework. This explanation in turn will provide an incentive for ANSPs in

other countries to adopt that same technology. One stakeholder noted that political interests can sometimes make it easier for a government to adopt solutions proposed by ICAO than those specifically proposed by the FAA or Europe. One stakeholder explained that ICAO's block upgrades can be useful for guiding the modernization process because they provide international endorsement of a path toward global harmonization. Other stakeholders acknowledged that the block upgrades are a reasonable framework, but thought that they will have little impact on NextGen or SESAR implementation plans because FAA's and EU's current plans go beyond the improvements outlined in the block upgrades.

FAA has also established working groups to coordinate with ANSPs from other countries, such as Japan and Canada. For example, FAA and the Japan Civil Aviation Bureau coordinate on the Future Air Transportation System Working Group which meets twice a year. The working group looks at a series of collaboration topics that are of mutual interest between the FAA and the Japan Civil Aviation Bureau. Similarly, according to officials from FAA and Nav Canada, both agencies have very active interaction at all levels from operational to planning and have external bilateral meetings twice a year to discuss technology and operational issues such as space-based ADS-B.

Sharing Best Practices

FAA helps achieve NextGen interoperability by sharing best practices with other countries and promoting NextGen capabilities to other countries, through technical assistance, training, organizing demonstrations, and participating in other programs. According to FAA, these efforts help to accelerate development and implementation of NextGen technologies, capabilities, and procedures. For example, FAA established technical-assistance working relationships with regional aviation-safety organizations and ANSPs in other countries, such as CAAS, to assist them in strengthening their capabilities to meet international aviation safety standards and ensure their systems are interoperable with NextGen. Most recently, according to CAAS officials, FAA has been providing CAAS with technical assistance related to several NextGen capabilities, including SWIM, to assist CAAS in exploring options for potential platforms and infrastructures to share information across the various ANSPs in the Asia Pacific region. A key consideration will be ensuring that the SWIM system developed in the Asia Pacific region is interoperable with NextGen, SESAR, and others' ATM systems.

FAA also uses the FAA Embry Riddle Testing Center and the FAA Florida NextGen Test Bed to host demonstrations of NextGen capabilities and technologies with foreign ANSPs, international partners and industry stakeholders. These demonstrations help further decisions on NextGen interoperability. For example, in 2014 FAA organized a “mini-global” SWIM demonstration at FAA’s NextGen Florida Test Bed, which allowed FAA, foreign ANSPs, and flight operators to test their ability to share real-time flight information worldwide using the SWIM network being developed for FAA to improve collaborative decision making, improve air-traffic management and promote international harmonization. The demonstrations included various international participants including representatives from ANSPs in Australia, Singapore, Thailand, South Korea, Japan, Canada, and Portugal. The “mini-global” demonstrations also helped determine whether U.S. capabilities and standards for exchanging flight, aeronautical and weather information–including the Flight Information Exchange Model, Aeronautical Information Exchange Model and Weather Information Exchange Model standards—were applicable globally. According to FAA officials, the information from the demonstrations will be used to strengthen these exchange models which are relatively new and still maturing. The information from these demonstrations will also help inform FAA and EU coordination on NextGen and SESAR interoperability. For example, according to FAA officials, these demonstrations will help identify any issues and mitigations that are required to ensure interoperability among the different SWIM architectures being developed in the U.S. and Europe. Also, stakeholders whom we interviewed, including representatives of one foreign ANSP that participated in these demonstrations, identified the mini-global demonstrations as an effective collaborative tool to further decisions on interoperability. The next demonstrations are scheduled for April 2016.

Conclusions

Given the global nature of the aviation system, collaboration—both across FAA as well as internationally—will be important to achieving NextGen interoperability and realizing the safety, efficiency, and environmental benefits of FAA’s ATM modernization efforts. As other countries begin to move forward with modernizing their ATM systems, it will be important that FAA continue to collaborate with international partners worldwide through working group forums and other mechanisms to ensure NextGen interoperability with other countries’ modernization efforts. FAA has taken positive steps to better coordinate its NextGen interoperability efforts across the agency—through the development of an international strategic plan and establishment of two internal bodies to guide and monitor

international activities—but the agency lacks a process for comprehensively assessing and managing potential NextGen interoperability risks on a routine basis. Stakeholders identified several factors such as resource and finance constraints and the timing of the implementation of ATM modernization efforts as factors that can affect the outcome of FAA's NextGen interoperability efforts. However, without a more comprehensive approach to risk assessment—key to a technically complex undertaking of this magnitude—FAA cannot develop an effective strategy—within FAA and with international partners—to mitigate risks and target and prioritize resources to best achieve its NextGen interoperability goals. Establishing timeframes to re-evaluate these risks on an ongoing basis could also help FAA more effectively adjust and reprioritize activities across the agency to mitigate potential risks to NextGen interoperability. In addition, documenting actions FAA plans to take to mitigate these risks would position FAA to better communicate to industry stakeholders, international partners and Congress its overall strategy and progress for achieving NextGen interoperability.

Recommendations for Executive Action

To implement a more effective international strategy for achieving NextGen interoperability with other nations, the Secretary of Transportation should direct the FAA Administrator to take the two following actions:

- conduct a risk assessment to identify potential threats and vulnerabilities to NextGen interoperability and establish timeframes for periodically re-evaluating these risks, and
- identify and document actions FAA will undertake to mitigate these risks, using information from the risk assessment as a basis for making management decisions about how to allocate resources for these activities.

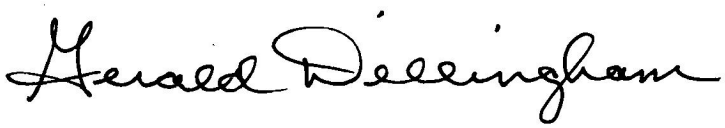
Agency Comments and Our Evaluation

We provided a draft of this report to the Department of Transportation (DOT) for review and comment. In its written comments, reproduced in appendix II, DOT stated that FAA concurred with our recommendations. In its comments, the department stated that FAA recognizes that risk assessments are an integral part of international harmonization work and discussed several FAA actions to identify risks, including cooperating with Europe, under SESAR to assess evolving information standards, operational changes, and implementation timing. These actions are important steps in assessing risks, and we believe that addressing our

recommendations will help FAA develop a more comprehensive and effective strategy to mitigate risks and target and prioritize resources to best achieve its NextGen interoperability goals. In addition to its written comments, DOT provided technical comments which we incorporated as appropriate.

As agreed with your offices, 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 of this report 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 website at http://www.gao.gov.

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



Gerald L. Dillingham, Ph.D.
Director, Physical Infrastructure Issues

Appendix I: Scope and Methodology

The objectives of this report were to examine: (1) factors selected stakeholders identified that might affect the global interoperability of the Next Generation Air Transportation System (NextGen); (2) the extent to which the Federal Aviation Administration (FAA) has established a strategy for achieving global interoperability of NextGen that includes key characteristics of effective strategies; and (3) actions FAA has taken to coordinate with the European Union (EU) and other countries on global interoperability and outcomes stakeholders identified from these actions.

To understand the nature of collaborative efforts between FAA and aviation stakeholders—both foreign and domestic—and to obtain stakeholders' perspectives on factors that might affect the global interoperability of NextGen, we interviewed FAA officials and a non-probability sample of 25 aviation stakeholders (see table 3).

Table 3: List of the 25 Aviation Stakeholders GAO Interviewed

Category	Subcategory	Stakeholder
Air Navigation Service Providers	Associations	Civil Air Navigation Services Organization (CANSO)
	International Air Navigation Service Providers	Air Services Australia
		Civil Aviation Authority of Singapore
		Nav Canada
Airlines	Associations	Airlines for America (A4A)
		International Air Transport Association (IATA)
	Passenger	American
		Delta
		United
Labor Unions and Professional associations	N/A	Air Line Pilots Association (ALPA)
Manufacturers and service providers	Aircraft	Airbus
		Boeing
	Associations	Aerospace Industries Association (AIA)
	Aviation equipment and systems	Harris Corporation
		Honeywell Aerospace
		ITT Exelis

Category	Subcategory	Stakeholder
European Union officials		EASA
		EUROCONTROL
		European Commission
		Single European Sky Air Traffic Management Research (SESAR) Deployment Manager
		Single European Sky Air Traffic Management Research (SESAR) Joint Undertaking
Research and development organizations	N/A	MITRE Center for Advanced Aviation System Development
Standards-making bodies	N/A	European Organization for Civil Aviation Equipment (EUROCAE)
		International Civil Aviation Organization (ICAO)
		Radio Technical Commission for Aeronautics (RTCA)

Source: GAO | GAO-15-608

We selected stakeholders based on our knowledge of the aviation industry and recommendations from interviewees. Specifically, we created an initial list of 20 stakeholders from across 7 different categories. We then selected an additional 5 stakeholders based on interviewee responses to our question on whom else they thought we should speak with. Specifically, we wanted to obtain perspectives from individuals and organizations with direct experience as users, or knowledge, through research or study, of global air-traffic management modernization activities and efforts to harmonize those activities where appropriate. As such, we sought the views of organizations that are involved in harmonization activities or who would be affected by global interoperability of NextGen. We divided stakeholders into the following seven groups: air navigation service providers (ANSP), airlines, labor unions and professional associations, manufacturers and service providers, EU officials, research and development organizations, and standards-making bodies. We used a semi-structured interview format with open-ended questions to obtain aviation stakeholder perspectives on the factors that might affect the global interoperability of NextGen. The results of our review are not generalizable to the industry as a whole, but provide insight and illustrative examples from a diverse group of stakeholders from across the various segments of the aviation industry. We analyzed the responses to these open-ended questions to identify the key factors mentioned by stakeholders and to provide examples of those factors.

To examine the extent to which FAA has established a strategy for ensuring global interoperability of NextGen, we analyzed FAA documents

and interviewed FAA officials to obtain information about FAA's recent efforts to develop an international strategy and to determine how, if at all, the strategy demonstrated characteristics of effective strategies previously identified by GAO.[1] Specifically, we evaluated FAA's international strategic plan and other supporting documents, including: FAA's 2014 NextGen Implementation Plan; FAA's fiscal year 2015 business plans; FAA's Strategic Priorities and Priority Initiatives; and FAA's fiscal year 2015 Performance Metric Scorecard. FAA officials told us that these supporting documents are related to FAA's international strategic plan. Collectively, these documents describe FAA's international strategy which supports its efforts to achieve global interoperability. Moreover we interviewed FAA officials about the contents and application of its strategy, the process for developing the strategy, and actions FAA intends to take to monitor the progress for implementing the strategy. We assessed FAA's strategy against each key characteristic and associated elements of effective strategies. As we reported in our prior work,[2] we identified these characteristics and associated elements by consulting statutory requirements pertaining to certain strategies we reviewed, as well as legislative and executive branch guidance for other national strategies.[3] We determined that a characteristic was: (1) "demonstrated" if FAA's international strategic plan or supporting documents provided support for all of the elements of a characteristic; (2) " partially demonstrated" if FAA's international strategic plan or supporting documents provided support for some but not all of the elements of a characteristics; and (3) "not demonstrated" if FAA's international strategic plan or supporting documents did not provide any support for elements of a characteristic.

To examine actions FAA has taken to coordinate with other countries on global interoperability, we obtained and reviewed key documents from FAA describing FAA coordination efforts and conducted interviews with

[1]GAO, *Combating Terrorism: Evaluation of Selected Characteristics in National Strategies Related to Terrorism*, GAO-04-408T (Washington, D.C.: Feb. 3, 2004).

[2]GAO-04-408T.

[3]In addition, as previously found, we also studied the Government Performance and Results Act of 1993 (GPRA), general literature on strategic planning and performance, and guidance from the Office of Management and Budget (OMB) on the President's Management Agenda. We also gathered published recommendations made by national commissions chartered by Congress; past GAO work; and various research organizations that have commented on national strategies.

FAA and aviation stakeholders. Specifically, we reviewed agreements between FAA and numerous international counterparts concerning collaborative research on air-traffic management.[4] We also reviewed documentation of global interoperability efforts from a number of stakeholders including the International Civil Aviation Organization (ICAO), the Single European Sky Air Traffic Management Research (SESAR) Joint Undertaking, MITRE,[5] and the Civil Air Navigation Services Organization (CANSO), and also examined FAA's involvement in these efforts. To evaluate how FAA's collaborative efforts with the EU compare with effective interagency collaborative practices, we reviewed our prior work evaluating FAA's efforts in 2011.[6] Then, using the same methodology, we compared key practices that we had previously identified for effective interagency collaboration, to current FAA collaborative efforts, such as those documented in the memorandum of

[4]These counterparts include the European Union, Nav Canada, the Civil Aviation Authority of Singapore, Air Services Australia, and the Civil Aviation Bureau of the Ministry of Transport of Japan.

[5]MITRE is a non-profit organization chartered to work in the public interest. MITRE manages four federally funded research and development centers, including one for FAA. MITRE has its own independent research and development program that explores new technologies and new uses of technologies to solve problems in the near term and in the future. It has also entered a joint venture with the Civil Aviation Authority of Singapore to create the Center of Excellence for Air Traffic Management.

[6]GAO, *Next Generation Air Transportation: Collaborative Efforts with European Union Generally Mirror Effective Practices, but Near-Term Challenges Could Delay Implementation*, GAO-12-48, Nov. 3, 2011 and GAO, *Results-Oriented Government: Practices That Can Help Enhance and Sustain Collaboration among Federal Agencies*, GAO-06-15, (Washington, D.C.: Oct. 21, 2005). In addition, GAO published recent reports that expand on the collaborative criteria discussed in GAO-06-15. Those reports include GAO, *Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanisms*, GAO-12-1022 (Washington, D.C.: Sept. 27, 2012) and GAO, *Managing for Results: Implementation Approaches Used to Enhance Collaboration in Interagency Groups*, GAO-14-220 (Washington, D.C.: Feb. 14, 2014).

cooperation and the 2014 NextGen-SESAR State of Harmonization Report, and those discussed with FAA officials.[7]

We conducted this performance audit from September 2014 to July 2015, 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.

[7]The seven collaborative practices that we previously identified included (1) defining and articulating a common outcome; (2) establishing mutually reinforcing or joint strategies to achieve the outcome and establishing compatible policies, procedures, and other means to operate across agency boundaries; (3) agreeing upon respective roles and responsibilities; (4) identifying and addressing needs by leveraging resources; (5) developing mechanisms to monitor, evaluate, and report the results of collaborative efforts, (6) reinforcing individual accountability for collaborative efforts through agency performance management systems; and (7) reinforcing agency accountability for collaborative efforts through agency plans and reports.

Appendix II: Comments from the Department of Transportation

U.S. Department of Transportation
Office of the Secretary of Transportation

Assistant Secretary for Administration

1200 New Jersey Avenue, SE
Washington, DC 20590

July 17, 2015

Gerald L. Dillingham
Director, Physical Infrastructure Issues
U.S. Government Accountability Office
441 G Street NW
Washington, DC 20548

As the Federal Aviation Administration (FAA) moves forward with its Next Generation (NextGen) Air Transportation System, achieving global interoperability is an intensive cooperative effort between the FAA and the international community. Risk assessment has always been an integral part of international harmonization work and we have established a formal risk-taking register to international interoperability.

The activities being addressed in cooperation with Europe under the Single European Sky Air Transportation Management Research Programme (SESAR) annex are items that have been assessed to be risks for interoperability and harmonization for the US and Europe. These areas are not limited to the type of standards commonly addressed by Radio Technical Commission for Aeronautics (RTCA), Aeronautical Radio Incorporated (ARINC) and SAE International (SAE). They also include evolving information standards and operational changes, such as advanced Performance Based Navigation procedures, and most recently Unmanned Aircraft Systems. As the report notes, the US and Europe are the two major modernization forces in the world. As part of the Standards Roundtable and the International Civil Aviation Organization update to the Global Air Navigation Plan, the FAA identified those standards that needed to be addressed globally to assure movement to NextGen and SESAR implementations. Moreover, FAA's international agenda does address issues broader than NextGen. It should be exceedingly clear that failure to achieve international harmonization and interoperability is not an option, and the FAA's international priorities reflect this fact.

As part of on-going risk assessment analyses, the issue of implementation timing is routinely considered. While concurrent timing is optimal for the harmonization of benefits, often the business, operational and budget drivers will make that difficult. As Europe leaves the planning stage of SESAR and enters the implementation phase, the FAA continues to work closely with its European counterparts on NextGen and SESAR, and on the development and deployment of our systems fully expecting that some adjustment to deployment dates will occur on both sides of the Atlantic. This is a key part of the evolving expansion of our trans-Atlantic agreement on air traffic modernization.

Upon review of the draft report, the FAA agrees with the two recommendations. The Department will provide a detailed response to the recommendations with 60 days after publication of GAO's final report.

We appreciate the opportunity to offer additional perspective on the GAO draft report. Please contact Patrick D. Nemons, Deputy Director of Audit Relations, at (202) 366-4986 with any questions or if GAO would like to obtain additional details about these comments.

Jeff Marootian
Assistant Secretary for Administration

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Gerald L. Dillingham, Ph.D., (202) 512-2834, or dillinghamg@gao.gov

Staff Acknowledgments

In addition to the contact named above, Heather Krause, Assistant Director; Amy Abramowitz; Delwen Jones; Hannah Laufe; Maria Mercado; Jaclyn Nelson; Josh Ormond; Kelly Rubin; Maria Stattel; and Sarah Veale made key contributions to this report.

Appendix IV: Accessible Data

Accessible Text and Data Tables

Data Table for Figure 1: Flight Profile in the Next Generation Air Transportation System (NextGen) Environment Envisioned by the Federal Aviation Administration (FAA)

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.
Domestic/oceanic cruise	Streamlined departure management	Allows multiple departure paths from each runway, thereby increasing departure capacity.
	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-15-608

Accessible Text for Figure 2: Examples of Air-Traffic Management (ATM) Modernization Programs Worldwide

- **Australia**;
- **Brazil**: Sirius Project (SIRIUS);
- **Canada**;
- **China**;
- **Europe**: Single European Sky ATM Research (SESAR);
- **India**: Future Indian Air Navigation Systems (FIANS);
- **Japan**: Collaborative Actions for Renovation of Air Traffic Systems (CARATS);
- **New Zealand**: New Southern Sky;
- **Russia**;
- **United States**: Next Generation Air Transportation System (NextGen).

Source: GAO. | GAO-15-608

Note: Australia, Canada, China, and Russia have modernization programs underway, but do not have umbrella names for these programs.

Data Table for Figure 3: International Civil Aviation Organization's (ICAO) Aviation System Block Upgrades

Number of modules

Projected initial operating capabilities date	Performance improvement areas				
		Airport operations	Globally interoperable systems and data	Optimum capacity and flexible flights	Efficient flight paths
2013	Block 0	5	4	3 [Note A]	3
2018	Block 1	6	4	4 [Note A]	2
2023	Block 2	3	3	2 [Note A]	2
2028 onward	Block 3	2	1	3 [Note A]	2

- Upgrades are organized into a series of four "**blocks**" linked to **four aviation improvement areas**. Each block has an initial operating capability target date which represents the earliest deployment date for the associated capability (technology or procedure).
- Each **block** is made up of **module groupings**. Each grouping represents a comprehensive deployable capability (technology or procedure).
- Each **module** defines a communication, navigation, or surveillance component upgrade required to deploy the technology or procedure.

Source: International Civil Aviation Organization (ICAO). | GAO-15-608

Note: The ICAO block upgrades (Blocks 0, 1, 2, and 3) refer to the target timelines for a group of capabilities (technologies and procedures) that will enable global interoperability in each of the four aviation performance improvement areas. The number of modules in a given block or aviation performance improvement area can vary.

Note A: Dependent modules across consecutive blocks represent a coherent transition over time, from basic to more advanced capability and associated performance.

Data Tables for Figure 4: Data Communications Implementation Schedule for the Federal Aviation Administration (FAA) and the European Union (EU), 2014 to beyond 2025

Year or range of years	FAA's Next Generation Air Transportation System (NextGen) implementation schedule
2014 and onward	**Future Air Navigation System 1/A (FANS 1/A)** is a data link system used for data communications between pilots and air traffic controllers. Many airlines already have aircraft equipped with FANS 1/A which is used in oceanic and some remote airspace. FAA is in the process of expanding this capability domestically.
2020 and onward	**Aeronautical Telecommunications Network (ATN) Baseline 2** is a more advanced digital communications infrastructure, providing additional capabilities for connecting different types of ground applications to corresponding air applications.
2020	Planned implementation of ATN avionics
Between 2021 and 2022	Planned implementation of ATN Baseline 2 ground system [Note A]

Year or range of years	EU's Single European Sky Air Transportation Management Research (SESAR) implementation schedule
2015 and onward	**Aeronautical Telecommunications Network (ATN) Baseline 1** is a digital communications infrastructure for connecting different types of ground applications to corresponding air applications. Implementation is in progress, but it is not fully operational.
2015	Planned ATN Baseline 1 equipage mandate
2018	Planned ATN Baseline 2 implementation
2020	Revised ATN Baseline 1 equipage mandate
2025 and onward	**ATN Baseline 2**
2025	Revised ATN Baseline 2 implementation (estimated) [Note A]

Source: GAO. | GAO-15-608

Note A: According to FAA officials, the estimated date for FAA's planned implementation of ATN Baseline 2 ground system is 2021 or 2022.

Agency Comments

Department of Transportation

Accessible Text for Appendix II: Comments from the Department of Transportation

Page 1

U.S. Department of Transportation
Office of the Secretary of Transportation
Assistant Secretary for Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

July 17, 2015

Gerald L. Dillingham
Director, Physical Infrastructure Issues
U.S. Government Accountability Office
441 G Street NW
Washington, DC 20548

As the Federal Aviation Administration (FAA) moves forward with its Next Generation (NextGen) Air Transportation System, achieving global interoperability is an intensive cooperative effort between the FAA and the international community. Risk assessment has always been an integral part of international harmonization work and we have established a formal risk-taking register to international interoperability.

The activities being addressed in cooperation with Europe under the Single European Sky Air Transportation Management Research Programme (SESAR) annex are items that have been assessed to be risks for interoperability and harmonization for the US and Europe.

These areas are not limited to the type of standards commonly addressed by Radio Technical Commission for Aeronautics (RTCA), Aeronautical Radio Incorporated (ARINC) and SAE International (SAE). They also include evolving information standards and operational changes, such as advanced Performance Based Navigation procedures, and most recently Unmanned Aircraft Systems. As the report notes, the US and Europe are the two major modernization forces in the world. As part of the Standards Roundtable and the International Civil Aviation Organization update to the Global Air Navigation Plan, the FAA identified those standards that needed to be addressed globally to assure movement to NextGen and SESAR implementations. Moreover, FAA's international agenda does address issues broader than NextGen. It should be exceedingly clear that failure to achieve international harmonization and interoperability is not an option, and the FAA's international priorities reflect this fact.

As part of on-going risk assessment analyses, the issue of implementation timing is routinely considered. While concurrent timing is optimal for the harmonization of benefits, often the business, operational and budget drivers will make that difficult. As Europe leaves the planning stage of SESAR and enters the implementation phase, the FAA continues to work closely with its European counterparts on NextGen and SESAR, and on the development and deployment of our systems fully expecting that some adjustment to deployment dates will occur on both sides of the Atlantic. This is a key part of the evolving expansion of our trans-Atlantic agreement on air traffic modernization.

Page 2

Upon review of the draft report, the FAA agrees with the two recommendations. The Department will provide a detailed response to the recommendations with 60 days after publication of GAO's final report.

We appreciate the opportunity to offer additional perspective on the GAO draft report. Please contact Patrick D. Nemons, Deputy Director of Audit Relations, at (202) 366-4986 with any questions or if GAO would like to obtain additional details about these comments.

Signed in place of Jeff Marootian
Assistant Secretary for Administration