U.S. Department of Transportation
Federal Aviation Administration

NextGen Annual Report

A Report on the History, Current Status, and Future
of National Airspace System Modernization

Fiscal Year 2020

CONTENTS

NextGen is a complex network of new and existing technologies, procedures, and policies that collectively work with the completed modernized infrastructure. Although funding for many of the programs described in this document can be traced to congressional authorization for NextGen, some systems funded through other sources enable full realization of NAS transformation. These non-NextGen programs are important to NAS transformation and are also covered in this document.

The U.S. National Airspace System (NAS) is the gold standard for air transportation systems anywhere in the world, and that level of excellence is due to our continuous efforts to make a very safe system even safer. We are always innovating.

Before the COVID-19 public health emergency, we were safely and efficiently moving about 50,000 flights and almost 3 million people a day. That's nearly a billion passengers per year. Operations have decreased drastically since March 2020, but our safety focus and our commitment to modernize have not wavered. Industry and FAA forecasts are predicting a return to 2019 air traffic levels by the middle of the decade, and our NAS must be ready when the industry recovers and demand returns.

With Congress' help and direction, we recently completed the infrastructure building blocks for this modernized NAS, better known as the Next Generation Air Transportation System, or NextGen. This report provides a consolidated snapshot of our progress, not including the impact of the COVID-19 public health emergency.

To advance modernization, we've been collaborating with the aviation community to deploy new capabilities at the right place and the right time. We've learned a great deal along the way, in particular that we have to work closely with airport communities that can potentially be affected by optimized flight tracks. We are identifying consensus solutions through our work with the congressional Quiet Skies Caucus, community roundtables, and other outreach efforts.

In addition to safety and efficiency benefits, the overall economic benefits from NextGen initiatives are adding up, with $7 billion in benefits delivered between 2010 and 2019. There's more to come as we fully operationalize NextGen with advanced capabilities that will increase capacity and flexibility, and deliver tens of billions of dollars more in benefits through the early 2030s.

Why is that so important? Because air traffic will return to and surpass 2019 levels. Along with traditional users, we have to efficiently integrate all operations, including drones, the advanced air mobility industry, and space operations—all of which are growing rapidly. To manage these activities effectively, we need an air traffic management system that is modern, connected, flexible, and lasting, and aerospace vehicles that are equipped with the avionics necessary to reap NextGen benefits.

With a modernized system, FAA employees have more and better data to track, separate, and manage aircraft, as well as predict their future location. Aircraft operators in many cases can fly shorter, more direct routes to arrive at their destinations more quickly, and their aircraft can burn less fuel and produce fewer emissions. Aviation stakeholders across the board have access to shared, on-demand information to make better decisions.

Now that the basic infrastructure is in place, we will begin implementing advanced capabilities while collaborating with our many stakeholders to incorporate training and change management into the FAA and aviation workforces. That means all employees will use new equipment in new operating environments with confidence as a new, modern, state-of-the-art NAS takes shape.

I thank Congress, FAA employees, and all our stakeholders for their hard work in deploying NextGen initiatives, and for helping us establish a course that will take us well into the future. I look forward to your continued support as we transition to a new, exciting phase in aviation that will include new users, operations, and endless possibilities for advancement, discovery, and, of course, safety.

Steve Dickson

FAA Administrator

The year 2020 marked a major milestone as we reached the halfway point in our planned implementation of the Next Generation Air Transportation System. This modernization effort, which we refer to as NextGen, is changing how people interact with the National Airspace System (NAS).

On a personal note, NextGen progress has been especially meaningful to me because I have witnessed the modernization of the NAS, firsthand, from the beginning, more than a decade ago. Our accomplishments stem from investment, commitment, hard work, and collaboration across the FAA and throughout the aviation community. It is rewarding to see how we are beginning to reap the benefits.

The foundational NextGen infrastructure is in place. Our enhancements to communications, navigation, surveillance, automation, and integration and information management systems are improving the lives of Americans. We are now leveraging the framework to operationalize NextGen by making all the components work together across aircraft and air traffic management systems. As a result, we are closer to our vision of managing air traffic more strategically through Trajectory Based Operations.

We will identify smarter, safer, and more efficient ways of providing NAS services to more users at more locations. Our investments ahead are aimed at integrating NextGen technologies and improving traffic flow management capabilities. We also plan to deploy innovative capabilities beyond the nation's largest and busiest airports.

NextGen is a success. Everyone involved in making it possible should be proud of their achievements. The years ahead will be marked with continued innovations and enhancements to our nation's air traffic system, and I look forward to celebrating more NextGen milestones with you.

> " NextGen has been a journey of change that required aviation experts across the country to engage and participate in making it real. Each and every one of you should pause and celebrate our collective accomplishments. "

Pamela Whitley
Assistant Administrator for NextGen

ECONOMIC IMPACT OF THE NAS

The United States operates the safest, largest, and most complex aviation system in the world, comprising 29.4 million square miles, or 17 percent of the world's airspace. Civil aviation supports 10.9 million jobs and accounts for 5.2 percent of the gross domestic product.

NextGen is critical to ensuring the NAS can safely accommodate anticipated growth and new types of aircraft, as well as protect aviation's $1.8 trillion contribution to the U.S. economy. Beyond its economic importance, aviation plays a vital role in the daily lives of all Americans. Before the COVID-19 public health emergency, almost 3 million passengers on nearly 50,000 flights moved through the NAS daily. This figure is the equivalent of transporting the entire population of Chicago. In addition to passengers, millions of people depend on aircraft every day for emergency management; the delivery of mail, food, and supplies; search and rescue; and other purposes.

According to a 2016 government analysis, flight delays and congestion cost the U.S. economy more than $20 billion each year. In addition, the report predicted the total number of people flying on U.S. airlines will increase by 50 percent over the next two decades. To ensure capacity keeps pace with increased demand, the FAA is changing the way we provide services through NextGen.

10.9 MILLION JOBS

$1.8 TRILLION ECONOMIC ACTIVITY

5.2% US GDP
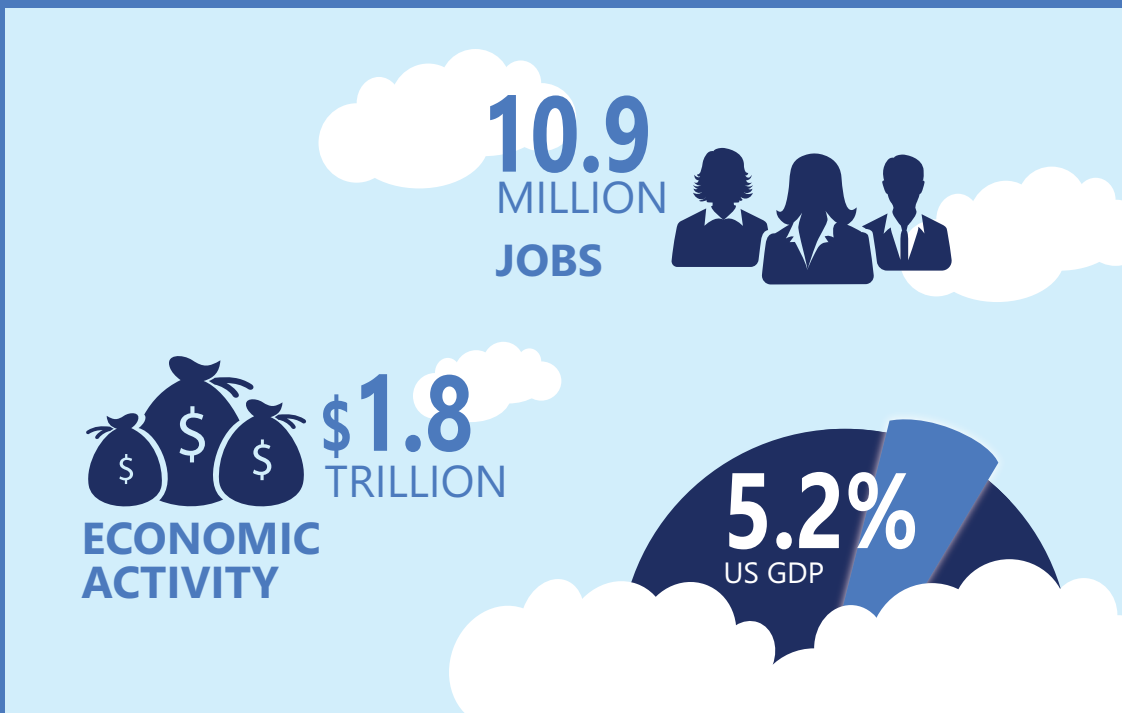
INTRODUCTION

NextGen: Transition to Trajectory Based Operations

For more than a decade, the Federal Aviation Administration (FAA) has worked with stakeholders in the aviation community to research, plan, build, and deploy NextGen, the Next Generation Air Transportation System. We are delivering on our promise to transform the aviation system and accommodate all users in a changing environment. We have modernized most of the foundational and enabling National Airspace System (NAS) infrastructure required for NextGen. NextGen provides the aviation community with the flexibility required to handle any demand. We recognize that the COVID-19 public health emergency has slashed domestic and international air travel this year. However, most forecasts are predicting a return to 2019 levels by 2024 or 2025. We must continue with NAS modernization to ensure we will be ready when the industry recovers and demand returns.

Our initiative is the comprehensive overhaul of the U.S. aviation system. It encompasses transformative technologies and processes that make air travel even safer and more convenient, efficient, and dependable.

NextGen is not one technology, product, or goal. Rather, it is a series of interlinked programs, portfolios, systems, policies, and procedures. It implements advanced technologies and capabilities that dramatically improve the operation of the NAS. Relying less on ground-based systems like radar,

NextGen is designed to transition the NAS from a traffic-controlled ground-based system to a traffic-managed satellite-based system. It is an evolution of air traffic management (Figure 1).

Advantages from these changes include improvements in safety, efficiency, and capacity in the NAS. NextGen features cutting-edge technologies that can play a critical role in lowering the rate of injuries, fatalities, and aircraft losses and damages. It also delivers financial benefits by reducing operating costs,

AIR TRAFFIC MANAGEMENT SYSTEM EVOLUTION

PROCEDURAL
Before 1950

Where We Think
the Aircraft Is

SURVEILLANCE
1950 – 2010

Where We Know
the Aircraft Is

TRAJECTORY
2010 and Beyond

Where We Know
the Aircraft Will Be
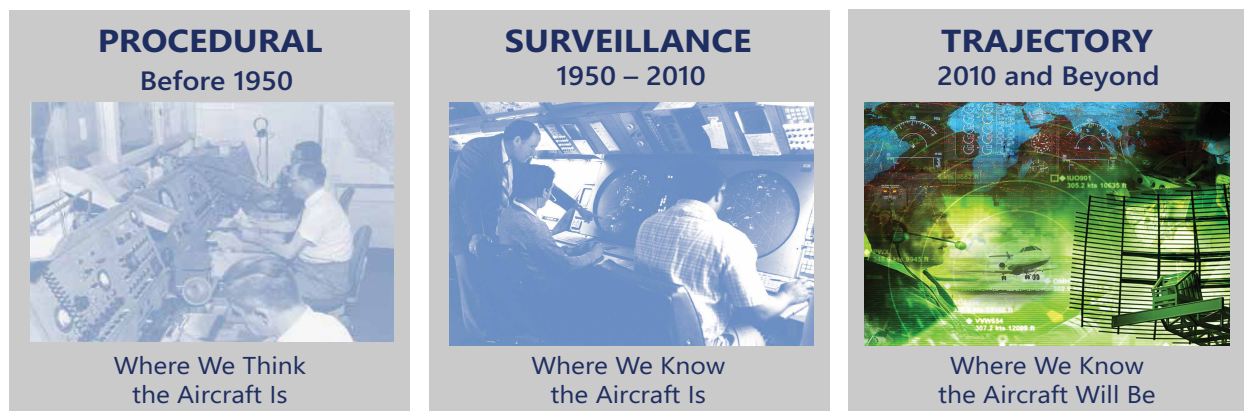
Figure 1: As technology changes, so has the way FAA controllers are able to separate and manage air traffic.

delays, and cancellations. Controllers and pilots are more productive using advanced technologies. By allowing for more direct and timely flights, NextGen mitigates aviation's environmental footprint.

Building the NextGen infrastructure laid the framework for the FAA's plan for Trajectory Based Operations (TBO), the end goal of our NextGen vision. TBO is an air traffic management method for strategically planning, managing, and optimizing flights throughout the operation. It uses time-based management, information exchange between air and ground

systems, and the aircraft's ability to fly precise paths in time and space. With TBO, controllers continue to assure separation based on where a flight is and improved predictions of where and when the flight is expected to be at key points.

This document serves as a singular report on NextGen progress and plans. It complies with congressional reporting requirements in the Vision 100 — Century of Aviation Reauthorization Act of 2003, FAA Modernization and Reform Act of 2012, and FAA Reauthorization Act of 2018.
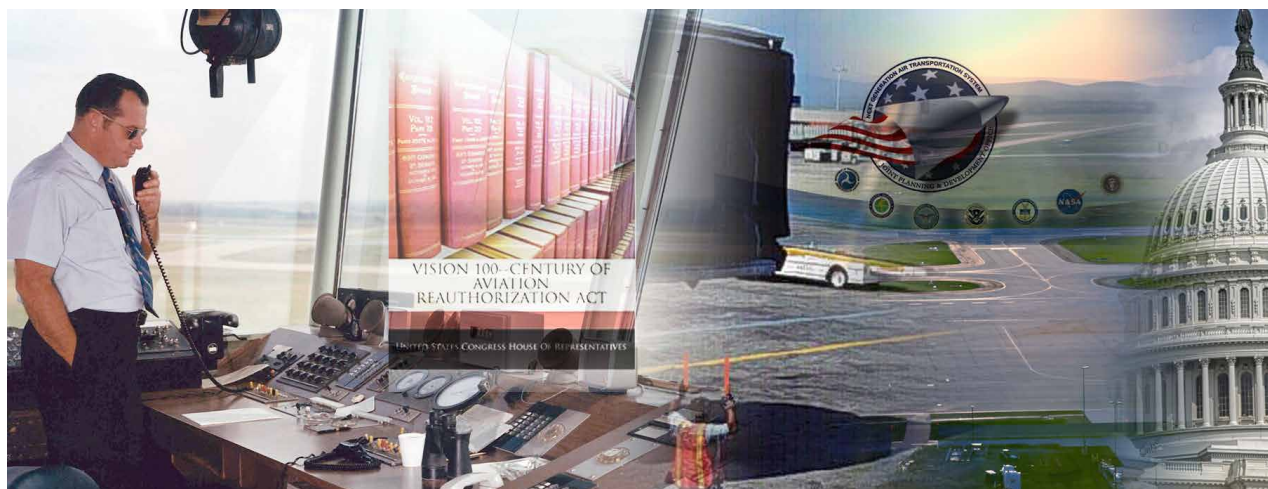
The Airline Deregulation Act of 1978 opened U.S. aviation to the free market and contributed to rapid growth in air travel. Flight options increased, leading to lower airfares, more passengers, and higher expectations from customers. By the late 1990s, the National Airspace System (NAS) was under stress due to mounting congestion, with about one in every four flights delayed. Representatives from the government, industry, and public were concerned about how the NAS could accommodate future air travel demands, given forecasts that, at the time, predicted large growth in aviation service needs through 2025. To resolve this challenge and ensure that the United States retained its leadership in global aviation, the federal government made major improvements in safety, security, and modernization.

Vision 100: Change Was Needed

We began to realize the need to modernize the NAS during the summer of 2000, when severe congestion and costly delays impeded air travel. Post-9/11 security requirements further constrained how people traveled and cargo moved. The Commission on the Future of the U.S. Aerospace Industry in 2002 recommended a multi-agency task force develop an integrated plan to transform the U.S. air transportation system.

In 2003, Congress passed the Vision 100 — Century of Aviation Reauthorization Act. It established the Joint Planning and Development Office (JPDO) to create a unified vision of what the U.S. air transportation system should deliver for the next generation and beyond. The JPDO was tasked with developing and coordinating long-term research plans, as well as sponsoring cross-agency mission research.

The result of JPDO's efforts was the 2004 creation of the Next Generation Air Transportation System Integrated Plan, which included a call for change. The report defined high-level goals and requirements to transform the NAS. In addition to the Department of Transportation (DOT) and Federal Aviation Administration (FAA), the plan involved other government agencies with responsibilities in air transportation, including the departments of Commerce, Defense, and Homeland

Security, and the National Aeronautics and Space Administration (NASA).

NextGen Vision Evolves

Working closely with stakeholders, the FAA researched the feasibility of advanced concepts and their associated benefits. The aviation community understood that many—yet not all—of the concepts would produce positive business cases. The FAA refined the path that NextGen planners envisioned by cutting and replacing some high-cost, high-risk, or low-benefit concepts based on research and industry feedback.

Concept of Operations Revealed

NextGen concept documents are designed to be iterative, meaning that they are revised as new information becomes available. Since the creation of the JPDO integrated plan, we fine-tuned the vision, clarified operational concepts, and validated strategies to provide greater insight into technologies that will modernize the NAS.

In 2007, the JPDO updated the original vision with the Concept of Operations for the Next Generation Air Transportation System to align with affordability and technical maturity. The document identified key research and policy issues that needed to be resolved to achieve national goals for air transportation. The FAA intended for the document to drive cross-agency research to validate the concepts, as well as eliminate operationally infeasible ideas.

The FAA published the NextGen Mid-Term Concept of Operations for the National Airspace System in 2011. The mid-term document is a stepping stone from the legacy system to the NextGen NAS envisioned by the JPDO. The document reflected areas to pursue during the transitional stage and updated implementation and program deployments. For example, the 2007 concept of operations was "curb-to-curb" in that it included passenger terminal operations. In the updated 2011 vision, the

FAA focused on components of the NAS falling under the FAA's responsibility, namely the "gate-to-gate" phases. It remained consistent with the JPDO's broad set of objectives, including maintaining safety and security, increasing capacity and efficiency, ensuring access to airspace and airports, and lessening effects on the environment.

In many cases, the mid-term concept of operations presented ambitious but not yet validated operational descriptions meant to maximize benefits and flexibility for NAS users. It outlined different potential outcomes for the future, which would depend on insights gained by evolving concepts. The FAA published The Future of the NAS in 2016 to explain how technology would be used to meet the original mid-term concept. The document reflected those insights from concept evolution and technology assessments and assisted the FAA in prioritizing future investments. It helped mature the vision for TBO.

Between the releases of these NextGen concept documents, the FAA also described how it would accommodate the continuous growth in scope of the NAS in other documents. We published the Integration of Civil Unmanned Aircraft Systems (UAS) in the NAS Roadmap in 2013 (updated in 2018), Performance Based Navigation NAS Navigation Strategy in 2016, Vision for Trajectory Based Operations in 2017, and UAS Traffic Management Concept of Operations in 2018 (updated in 2020).

Collaborating with the Aviation Community

In 2010, the DOT established the NextGen Advisory Committee (NAC) as a federal body responsible for responding to specific assignments from the FAA. Membership includes 30 senior executives representing aircraft operators, international stakeholders, airports, labor unions, manufacturers, environmental interest groups, the Department of Defense, and NASA.

The advisory committee completes assignments related to concepts, requirements, operational capabilities, the associated use of technology, and related considerations to operations that affect the future air traffic management system. Additionally, it proposes nonbinding recommendations to the FAA through a task response process. For example, the NAC identified the highest-benefit NextGen capabilities for stakeholders. The NextGen Priorities Joint Implementation Plan, first published in 2014 and since updated, describes ready-to-implement activities that align FAA and aviation community priorities.

The FAA and its international partners work through the International Civil Aviation Organization (ICAO) to develop a globally connected and harmonized air traffic management system. As the aviation technical body of the United Nations, ICAO provides a forum for its 192 member states to adopt and implement international aviation standards. The FAA provides representatives for all expert panels considered necessary for international harmonization. By influencing plans through working groups, we help direct global air traffic modernization and mitigate operational risks. The FAA helped lead the revision of the global air traffic management roadmap described by the ICAO Global Air Navigation Plan, which defines the course of world aviation systems for the next 20 years.

The FAA collaborates directly with key international partners and regional groups on relevant air traffic management modernization topics. For example, together with the Single European Sky Air Traffic Management Research (SESAR) organization, we periodically update the NextGen–SESAR State of Harmonisation, which summarizes progress toward global interoperability between the continents. We maintain international agreements with the
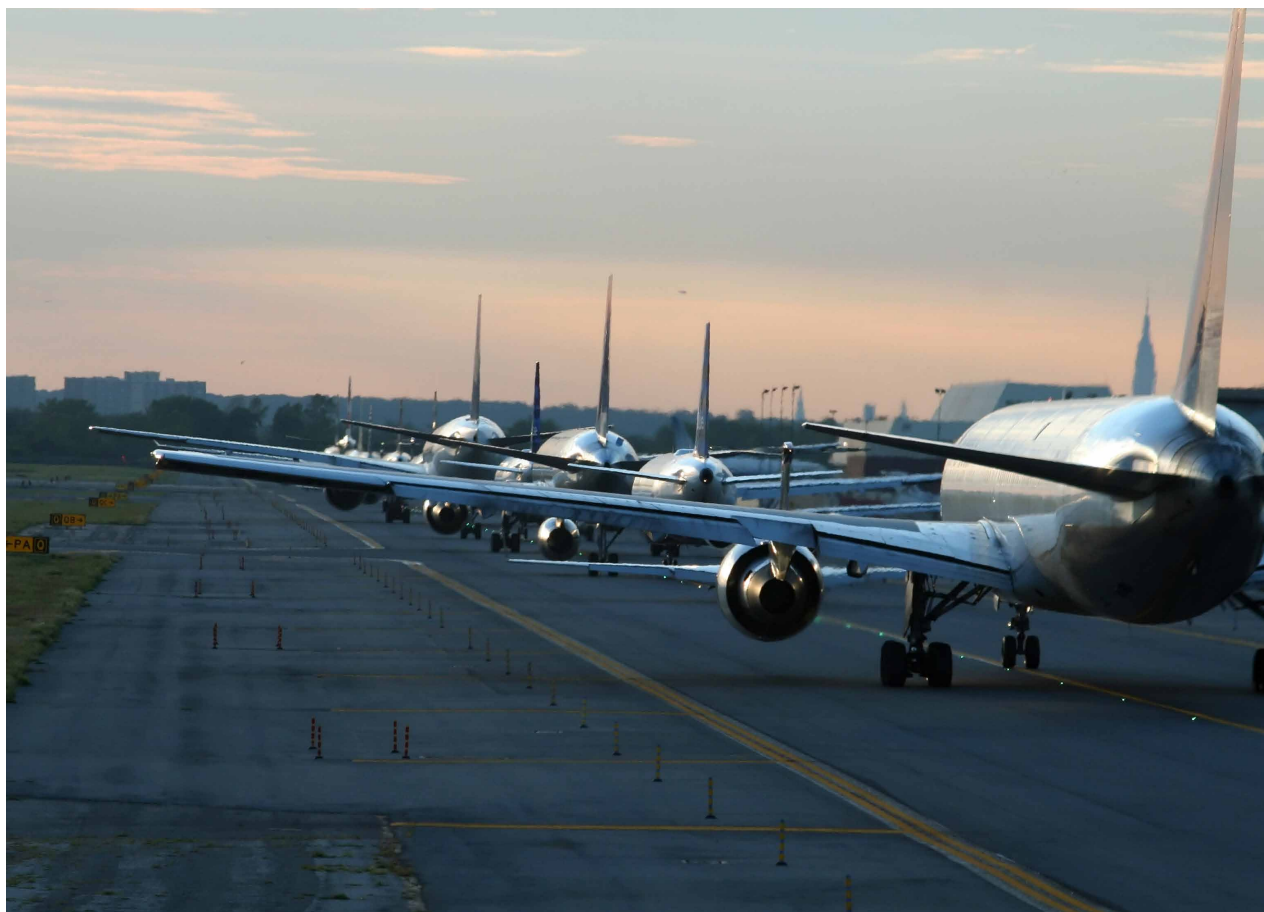
European Union, Japan, and Singapore for joint research and development of future air traffic systems.

Through these agreements, the FAA engages its partners to support the adoption of U.S. standards as globally accepted standards. We also participate with the U.S. Trade and Development Agency and Department of Commerce to cooperate with Brazil, China, and India to ensure U.S. aviation standards are accepted worldwide. Collaborating with the international aviation community will result in greater interoperability of avionics, communications protocols, and operational methods.

Coordinating with Federal Partners

Our engagement with external government agencies through the NextGen Executive Board, NextGen Executive Weather Panel, and other collaborative bodies allows us to leverage stakeholder expertise while gathering resources to advance NAS modernization. We work closely with the departments of Commerce, Defense, and Homeland Security; NASA; National Geospatial Intelligence Agency; National Transportation Safety Board; and other critical contributors as needed.

Involving the FAA Workforce

The FAA workforce is an essential component of NextGen development. Our labor unions collaborate with the FAA at national, regional, and local levels to better understand requirements and contribute to a changing aviation system. These unions coordinate with their memberships to find subject matter experts to participate in and co-lead design teams, human-involved assessments, and program development and implementation. As we lay the foundation for the airspace system of the future, the FAA workforce is represented on NextGen working groups to communicate recommendations and to ensure employees have the training necessary to operate the future NAS.

Developing and Validating Concepts

The FAA established the Florida NextGen Test Bed in 2008 to generate industry-driven concepts that advance NextGen. Located next to Daytona Beach International Airport and near Embry Riddle Aeronautical University in Daytona Beach, FL, the research facility provides a platform where early-stage NextGen concepts can be integrated, demonstrated, and evaluated. Industry partners meet at the test bed to incorporate their NextGen products into the NAS in a controlled setting. The facility contains more than two dozen NAS systems. For multi-site demonstrations, it can remotely connect with other FAA laboratories, government partner sites, industry, and academia.

Another test facility was dedicated in 2010: the NextGen Integration and Evaluation Capability Laboratory at the FAA William J. Hughes Technical Center near Atlantic City, NJ. Using simulated and actual NAS equipment, the facility provides a futuristic NextGen gate-to-gate environment with advanced data collection capabilities to support integration and evaluation of new technologies and concepts. Researchers can complete human-involved simulations, proof-of-concept studies, rapid prototyping, and concepts validation and maturation to improve operational performance across all NextGen technologies. This facility complements and connects with the other laboratories at the Technical Center, the Florida NextGen Test Bed, and laboratories located at non-FAA facilities.

In 2012, the FAA designated the NASA/FAA North Texas Research Station as a NextGen test facility. It is located near several air traffic control facilities, airports, and airline operations centers in the Dallas/Fort Worth area. The facility can access a variety of NAS data that enhance the evaluation of advanced technologies for NextGen and simulate air transportation operations. The laboratory is managed by NASA Ames Research Center Aviation Systems Division. It operates in all phases of NextGen research, beginning from

early concept development to field evaluations of prototype systems. This facility has transitioned advanced NextGen concepts and technologies that were later provided to the FAA through technology transfers.

Through the FAA Air Transportation Centers of Excellence (COE), the FAA works with schools and their industry affiliates to advance aviation technologies. This cooperation is critical for training the next generation of aviation scientists and professionals. Some of the 13 focus areas are UAS, commercial space transportation, alternative jet fuels, and mitigation of aircraft noise and aviation emissions. MITRE's Center for Advanced Aviation System Development, a federally funded research and development center, also continues to support FAA research in NextGen decision support systems and TBO concepts.

From Vision to Reality

Modernization of the U.S. air transportation system is a significant and critical undertaking. NextGen is a complex, large-scale system of systems, policies, and procedures deployed over more than two decades. To the casual observer, its development and implementation may be difficult to follow. With complexity comes challenges of technologies typically in various stages of lifecycle management, from research and development to technical refreshes. To better understand the relationships of NextGen programs, the FAA uses planning reports to map the evolution from the legacy NAS to NextGen.

To manage NextGen with short-term funding horizons, the FAA rolled out improvements in smaller increments with more program segments to ensure affordability. The FAA defined four 5-year segments to assist in planning NextGen investments. We have scheduled initial implementation of all major planned systems by 2025, but not the full integration necessary to provide the complete set of anticipated NextGen benefits. Beyond 2025, the FAA expects to accrue benefits through enterprise-level advanced applications, additional aircraft equipage, and full adoption of TBO.

NAS Enterprise Architecture

To identify how to transform the NAS, the FAA built the NAS Enterprise Architecture, which describes the evolution of air traffic control through our implementation of infrastructure, technologies, and new services. It documents current and future mission-critical and mission-support systems. The enterprise architecture also contains roadmaps to help identify, track, and mature concepts that will further advance the NAS.

The enterprise architecture helps us transform the NAS by clearly communicating system responsibilities while enhancing NAS operations. This architecture eases how we consolidate functions and systems while continuing to satisfy the aviation community's changing needs.

NAS Segment Implementation Plan (NSIP)

Supporting the NAS Enterprise Architecture is the NSIP, the FAA's blueprint for developing, integrating, and implementing NextGen capabilities. The NSIP provides the framework for understanding interdependencies among operational improvements, increments, systems, and investment decision points.

The NSIP serves important, distinct purposes for different NAS users. Program managers, engineers, and acquisition teams use the resource to plan NextGen milestones. External stakeholders, such as advisory organizations, use the plan to identify and prioritize capabilities.

NextGen Portfolios and Programs

The FAA uses a portfolio approach to group related initiatives for assessing, developing, and implementing new capabilities. We implement each operational improvement through a series of incremental capabilities that provide individual benefits. Combined, they transform the way we operate the NAS. Appendix A details the operational improvements and associated increments within the port-

BENEFITS OF NAS MODERNIZATION

Improvements from new technologies, capabilities, and procedures through NAS modernization provide benefits in one or more of these areas:

Access and Equity	Provides an operating environment that ensures that all airspace users have right of access to the air traffic management (ATM) resources needed to meet their specific operational requirements and that the shared use of airspace by different users can be achieved safely. The global ATM system should ensure equity for all users that have access to a given airspace or service. Generally, the first aircraft ready to use the ATM resources will receive priority except where overall safety or system operational efficiency would accrue, or national defense considerations or interests dictate that priority be determined on a different basis.
Capacity	Exploits the inherent capacity to meet airspace user demands at peak times and locations while minimizing restrictions on traffic flow. To respond to future growth, capacity must increase, along with corresponding increases in efficiency, flexibility, and predictability, while ensuring that there are no adverse impacts on safety and giving due consideration to the environment. The ATM system must be resilient to service disruption and the resulting temporary loss of capacity.
Efficiency	Addresses the operational and economic cost-effectiveness of gate-to-gate flight operations from a single-flight perspective. In all phases of flight, airspace users want to depart and arrive at the times they select and fly the trajectories they determine to be optimum.
Environment	Contributes to the protection of the environment by considering noise, emissions, and other environmental issues in the implementation and operation of the aviation system.
Flexibility	Ensures the ability of all airspace users to modify flight trajectories dynamically and adjust departure and arrival times, thereby permitting them to exploit operational opportunities as they occur.
Predictability	The ability of airspace users and ATM service providers to provide consistent and dependable levels of performance. Predictability is essential to users as they develop and operate their schedules.
Safety	Uniform safety standards and risk and safety management practices should be applied systematically to the air transportation system. In implementing elements of the system, safety needs to be assessed against appropriate criteria and according to appropriate and globally standardized safety management processes and practices.

The benefit areas described above map to improvements listed in Appendix A detailed work plans.

folios, including implementation timelines through 2025.

The FAA manages NextGen programs to ensure they meet stringent safety standards and deliver intended benefits described in program-specific business case analysis reports. Appendix B reports on the return on investment of major NextGen programs.

Safety

Because the benefits of new capabilities must align with the safe operation of the NAS, all new capabilities are implemented only after thorough safety testing. The FAA conducts NextGen-unique safety risk management for research and development, prototyping, testing and evaluation, and flight trials and demonstrations. We incorporate risk-based decision-making to support agency-wide safety initiatives. Along with resources, such as the Hazard Identification, Risk Management, and Tracking Tool; the Aviation System Information Analysis and Sharing; and the System Safety Management Transformation, program teams can access centralized data to provide a holistic perspective on system risks. The NextGen Safety Management System emphasizes safety management as a fundamental business process that we must place with the same high priority as other important organizational functions.

Our investment in foundational infrastructure and early NextGen technologies are changing how people interact with the National Airspace System.

WHERE WE ARE TODAY:
DELIVERING ON THE PROMISE
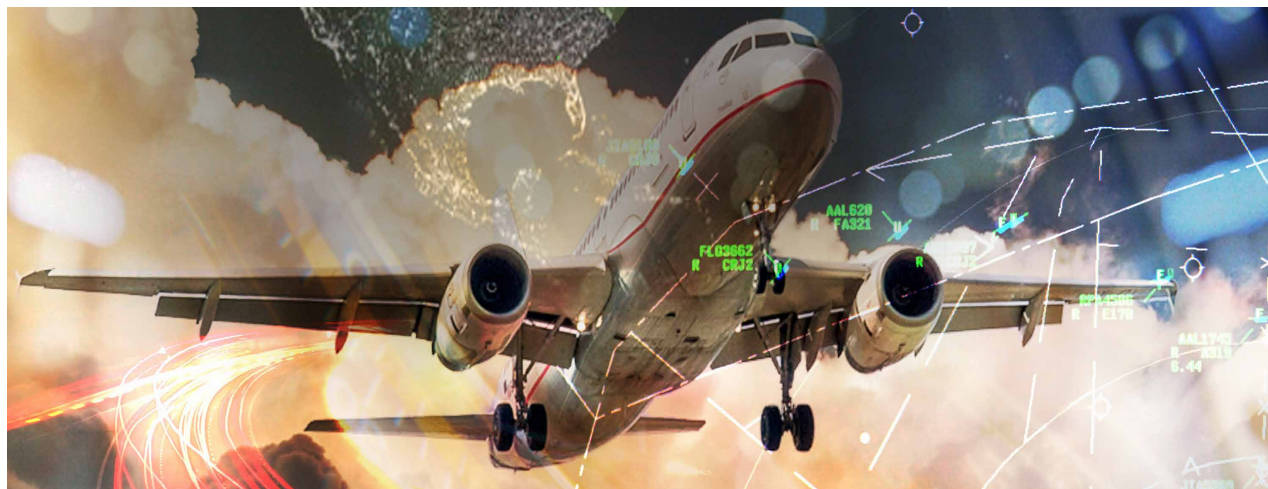
A s the NextGen concept formed, the Federal Aviation Administration (FAA) planned for its implementation. We worked with the aviation community to identify capabilities that could be accomplished using existing aircraft equipage. This strategy enabled airspace users to realize early benefits from modernization while keeping NextGen on course to achieve its long-term goal of Trajectory Based Operations (TBO). Next, based on previous lessons learned, we determined the best way to modernize was with a new infrastructure that could accommodate state-of-the-art enabling technologies and advanced capabilities rather than adding one-off improvements to an aging infrastructure that could not accommodate broader transformation. Today, most of the foundational and enabling elements of the 21st century infrastructure we envisioned for NextGen are in place and are already delivering benefits.

Foundational Technology

The FAA has deployed new hardware and software automation platforms and procedures that air traffic controllers use to separate aircraft and ensure safety in the National Airspace System (NAS). En Route Automation Modernization (ERAM) and the Standard Terminal Automation Replacement System (STARS) allow controllers to work more productively. ERAM and STARS support NextGen goals with modern software architectures that serve as the platform for new air traffic management capabilities.

Beyond these foundational systems, the FAA identified essential enabling systems that improve communications, navigation, surveillance, traffic flow decision support automation, and information sharing. Figure 2 shows how NextGen infrastructure is enabling the transformation of our air traffic management operations. The sections that follow further detail these important innovations.

Data Communications (Data Comm)

Historically, pilots and controllers communicated primarily by voice over the radio. Though voice is an immediate way to communicate with an aircraft, it can be time-consuming to give and confirm instructions, especially during multiple aircraft reroutes. In addition, a pilot using voice communications may misunderstand or fail to hear a message,

BEFORE AND AFTER NEXTGEN

PAST PRACTICES	ENABLING PROGRAMS	NEXTGEN IMPROVEMENTS
Voice-only communications	Data Communications (Data Comm)	Digital communications
Ground-based routes and procedures	Performance Based Navigation (PBN)	Satellite-enabled routes and procedures
Radar-only surveillance	Automatic Dependent Surveillance – Broadcast (ADS-B)	Satellite-enabled near real-time surveillance
Tactical and reactive air traffic control	Decision Support System (DSS) Automation	Strategic integrated air traffic management
Point-to-point, segmented information sharing*	System Wide Information Management (SWIM)	Enterprise-level information sharing*

* The FAA shares information on SWIM and other channels in accordance with our policy on protecting sensitive unclassified information.

Figure 2: NextGen infrastructure is enabling the transformation of our air traffic management.

or perhaps act on directions meant for another aircraft. To supplement voice communications and avoid these challenges, the FAA began developing Controller Pilot Data Link Communications (CPDLC) in the 1990s, initially to support flights over oceans. Data Comm applications like CPDLC provide air traffic controllers and pilots with the capability to quickly and accurately send, review, and accept text-like digital messages. Air carrier flight operations centers receive the same information at the same time as the flight deck, providing decision makers with shared awareness for faster reaction and agreement to flight changes.

The FAA is delivering Data Comm services to transform NAS operations while working with aircraft operators, airframe and avionics manufacturers, and commercial communications service providers. We anticipate Data Comm will save operators more than $10 billion during the program's 30-year lifecycle; the FAA will save about $1 billion in future operating costs.

Data Comm Tower Service

Data Comm Tower Service provides CPDLC digital departure clearances. These clearances are the instructions pilots receive before takeoff to get to their destinations. Controllers send more than 8,500 Data Comm departure clearances every day.

The FAA completed its original commitment for Data Comm Tower Service to 55 airports in December 2016, $72 million under budget and almost 30 months ahead of schedule. We then deployed this service to an additional seven airports, which were completed in August 2018, almost 13 months ahead of schedule.

Benefits of Data Comm in the Operation
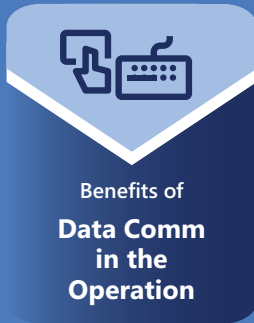
Between June 2016 and January 2020, **CPDLC technology**:

- Cleared more than 7.5 million departures
- Prevented more than 118,200 read-back errors
- Reduced delays by nearly 1.4 million minutes (about one-third of the savings are attributed to taxi-out, and the rest are at the gate)
- Saved 2.07 million minutes in radio communication time
- Prevented 17.1 million kilograms of carbon dioxide emissions

More than 6,000 aircraft flown by more than 75 domestic and international air carriers, as well as several dozen business jet operators, are equipped for this service. When weather or other factors delay departures, revised clearances sent through Data Comm improve accuracy and controller productivity. Controllers can deliver multiple CPDLC messages in the time it would take to do one clearance via voice, which improves taxi-out times and airport traffic flow. During severe weather, some aircraft have saved more than 90 minutes of delay time.

Performance Based Navigation (PBN)

From the mid-1940s to the turn of the century, the ground-based Very High Frequency Omnidirectional Range (VOR) system was the predominant navigation aid used by pilots. Distance Measuring Equipment (DME) is another common type of ground-based radio navigational technology. Yet reliance on infrastructure on the earth's surface limits the availability of routes. Pilots using these navigation aids fly in a zigzag path, meaning that routes are less direct and more time-consuming.

In the 1980s, operators began equipping aircraft with the Flight Management System and computers featuring multiple navigation avionics. The enhancements, working with VORs and DMEs, allowed computers to calculate a route between two arbitrary points without the aircraft flying directly over fixed stations on the ground. This change was the start of what is known as area navigation (RNAV).

Positioning accuracy increased with the advent of GPS as a new navigation sensor. Specialists who designed flight paths could now create routes and procedures and specify aircraft performance without relying on ground-based navigational aids.

As GPS was included in the multi-sensor systems or as a stand-alone capability, Required Navigation Performance (RNP) was formed. RNP described how aircraft may fly an RNAV route or procedure using either ground-based or satellite-based navigation, as long as they can achieve the required performance. The required performance is directed when position accuracy is essential to separation, best use of airspace, and in some cases, obstacle clearance. RNP requires aircraft to have on-board monitoring to ensure performance compliance and alert the pilots if the aircraft flies outside of a specified area. Pilots can fly reliable, predictable, and repeatable procedures with tighter tolerances and constant radius turns.

PBN arose as a way to describe performance capabilities for RNAV and RNP. Both types of PBN allow equipped aircraft to fly shorter and more efficient flight paths, which reduce fuel consumption and engine exhaust emissions while improving schedule adherence. The FAA's concept of operations for PBN is to establish specified, repeatable flight paths where needed. We employ PBN for congested airspace, reduced or relocated ground navigational aids, or improved airport access.

Since 2015, PBN procedures and routes are the NAS standard during normal operating conditions. The FAA has published more than 9,600 PBN routes and procedures, including departure, arrival, and approach procedures for more than 500 airports.

Not all types of PBN procedures are suitable for every airport or phase of flight. The FAA works with the aviation community to determine if a PBN procedure is worthwhile based on air traffic, airspace, airport, and community factors, as well as a cost-benefit analysis. Conventional procedures provide options to accommodate non-equipped users. The following examples show how PBN initiatives make a difference for pilots and aircraft operators.

Equivalent Lateral Spacing Operations (ELSO)

In 2015, ELSO became a national separation standard for departing aircraft. ELSO allows controllers to space flight paths closer together and safely clear aircraft for takeoff more efficiently. This standard is possible because aircraft equipped for PBN can fly repeatable and predictable RNAV Standard Instrument Departures (SID).

RNAV SIDs provide fixed paths for aircraft from takeoff to en route airspace with minimal level-offs. Standard flight paths simplify navigation tasks for controllers and pilots in all weather conditions. They do not have to issue and follow step-by-step climb and turn instructions.

Low- and High-Altitude Routes

The FAA is replacing conventional low- and high-altitude routes that used VOR navigational aids with PBN RNAV T-Routes for low altitudes and Q-Routes for high altitudes.

- The FAA is canceling many VOR-based "Victor routes" for GPS-enabled T-Routes for flights from 1,200 feet above ground level to 18,000 feet mean sea level. The FAA has published about 110 T-Routes.

- By 2030, most VOR-based "Jet routes" between 18,000 and 45,000 feet mean sea level will be cancelled in domestic airspace. There are now more than 160 Q-Routes.

Standard Terminal Arrival (STAR) with Optimized Profile Descent (OPD)

As flights descend from cruising altitude to an airport, aircraft traditionally level off at different altitudes as they are handed off from controller to controller or to deconflict the aircraft with other flights. These stairstep-like descents consume more fuel as pilots need to increase engine thrust to maintain flight at the different altitudes.

STARs with an OPD have several advantages. Using the flight computer to program optimal speed and altitude requirements for various points along the route, aircraft can glide continuously at near-idle engine speed from the top of the descent to landing with minimal level-off segments. Aircraft can maintain higher, more fuel-efficient altitudes closer to the airport. Pilots can avoid using speed brakes and frequent thrust adjustments.

Established on RNP (EoR) Separation

At certain airports, air traffic controllers can use multiple parallel runways to increase arrival capacity. RNP approaches with a radius-to-fix leg allow for aircraft to approach their respective runway from the opposite direction of their eventual landing with a smooth

U-turn. EoR is the separation standard that enables these aircraft to turn on RNP or RNAV approaches simultaneously while other aircraft are conducting instrument approaches to a parallel runway. EoR separation makes flying RNP or RNAV procedures easier, increasing PBN use and its benefits, such as reduced pilot-to-controller communications and more stabilized approaches. The FAA approved EoR separation for widely spaced parallel runways in 2015 and for simultaneous dual and triple independent runway approaches in 2018.

Metroplex

A metroplex is a metropolitan area with multiple airports and complex air traffic flows. Each metroplex involves a unique system of airports, aircraft, geography, and weather patterns. The optimization of airspace using PBN and publication of procedures in each metroplex are multi-year initiatives that

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Benefits of PBN in the Operation
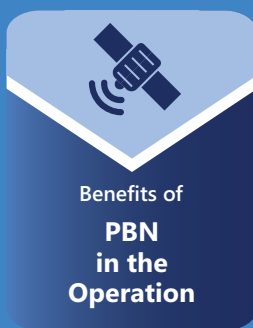
With **ELSO** in use at Hartsfield-Jackson Atlanta International Airport (ATL), four flights can depart in the same area that previously accommodated three flights. Controllers in Atlanta can clear as many as 8–12 more departures every hour.

At one Washington en route center sector, four **Q-Routes** replaced two Jet routes, allowing for greater traffic flow in this part of the country. The Q-Routes give the major airports in the Washington, DC, area dedicated PBN routes, which allow air traffic controllers to better manage traffic flow for aircraft going to the different airports. In the past, controllers at those airports relied on work-intensive radar vectors to direct aircraft from a route to arrival and approach procedures for the airports.

At Minneapolis-St. Paul International Airport (MSP), 79 percent of equipped aircraft land using a **STAR with an OPD**. Based on reduced fuel burn, arriving aircraft emit 28,000 fewer metric tons of carbon dioxide into the atmosphere annually. This reduction is equivalent to removing more than 12,000 cars from the road, and it equates to more than 42 percent of the total emissions attributed to electricity use at the airport. Airport management reported that implementation of OPDs represented the biggest single action to reduce greenhouse gas emissions at the airport.

The **EoR separation standard** is available at Denver International (DEN), Houston's George Bush Intercontinental (IAH), and Seattle-Tacoma International (SEA) airports. The operation at DEN has been shown to shorten the path each aircraft takes to the runway by about 6 nautical miles in visual conditions and close to 30 nautical miles in instrument conditions. The shorter flight segments reduce flight times, fuel burn, and carbon emissions.

provide major benefits in congested airspace near busy airports.

Study teams made up of air traffic controllers, pilots, airport operations, and technical staff analyze a metroplex's operational challenges and explore opportunities to improve operations.

FAA teams engage affected communities on the scope of airspace modernization, considering the FAA's responsibilities under the National Environmental Policy Act.

A standardized way to how and when the FAA engages airports and other stakeholders during Metroplex projects was developed and deployed for those projects still in progress and has been adapted for use on future PBN projects. Policy and guidance documents have been updated, renewing the FAA's commitment to involving the community and reflecting the additional community involvement activities and stakeholder engagement expected to happen during PBN projects. The FAA is continually working to develop further guidance, resources, tools, and practices to effectively involve stakeholders.

The FAA chose 11 metropolitan areas for the Metroplex program in response to recommendations from the aviation community. Implementation is complete for nine of these areas and expected for Las Vegas and South-Central Florida by 2022. Additionally, the FAA incorporated large-scale redesign of airspace for 29 busy airports not meeting Metroplex program criteria.

Automatic Dependent Surveillance–Broadcast (ADS-B) In and Out

The aviation community marked a turning point in its history on January 1, 2020: The FAA's ADS-B Out rule went into effect. The rule requires aircraft flying in most controlled airspace to be equipped with this more precise surveillance technology.

Benefits of

ADS-B Out in the Operation

ADS-B Out is providing benefits for areas previously without radar coverage. In the Gulf of Mexico, ADS-B Out boosts capacity from 75 to 80 aircraft per hour, saving an average of 7-11 minutes on special routes. For helicopters equipped with ADS-B Out traveling to oil platforms, controllers can decrease separation distance from 15 nautical miles to 5 nautical miles. ADS-B is expected to save operators about $70 million by 2035 by enabling a greater number of flights over the Gulf.

Air traffic controllers use this technology to identify, determine position and altitude, and monitor the aircraft for safe separation. Since the 1950s, radar technology provided controllers with this information.

However, ADS-B is now the preferred method of surveillance for air traffic control in the NAS, allowing controllers to track aircraft more frequently and consistently than traditional radar.

ADS-B technology helps to remove blind spots, boosting safety and efficiency while easing the workload for controllers. At the nation's busiest airports, improved accuracy and enhanced tracking of ADS-B provides aircraft position information at lower altitudes farther from an airport. At more than 450 smaller airports throughout the United States, ADS-B provides coverage at significantly lower altitudes than previously possible using radar. The increased coverage allows controllers to track

airplanes to the final approach fix, the last leg in an aircraft's path to landing, and reduces the number of airports where "one-in, one-out" service is required.

ADS-B Out enables aircraft to broadcast their position, ground speed, and other surveillance data every second. The improved accuracy and reliability of GPS compared to radar means controllers will be able to safely reduce the minimum separation distance between aircraft for non-radar airspace and increase capacity in the nation's skies. A network of nearly 700 ADS-B ground stations supports this aircraft surveillance technology.

ADS-B In equipment allows aircraft to receive and display the ADS-B Out data of other participating aircraft, enabling safer and more efficient flying. For the first time, pilots with ADS-B In equipment can see what air traffic controllers see, operating with a shared awareness of conflicting air traffic.

Although ADS-B In was precluded from the mandate, the technology offers many advantages. Equipped aircraft can receive traffic, flight, and weather information services at no additional cost to the operator. Pilot applications include a traffic advisory system to detect and avoid potential conflicts, advanced interval management, and In-Trail Procedures, which enable aircraft to fly at optimal or less turbulent altitudes during oceanic flights.

Decision Support System (DSS) Automation

Three decision support hardware and software systems enable controllers, traffic managers, and other stakeholders to quickly and efficiently respond to evolving traffic and weather conditions. DSSs improve common situational awareness through information sharing. Additionally, DSSs maximize efficiency, balance demand to capacity, and reduce delays through each phase of flight. Aircraft operators and passengers benefit from more orderly taxiing and flexible airspace routing, which leads to smoother, faster, and more cost-efficient flights. Each DSS has a specific role and together provide an integrated, responsive, and collaborative way to manage traffic flow.

Traffic Flow Management System(TFMS)

TFMS, the NextGen version of the legacy Enhanced Traffic Management System, can predict air traffic volume, gaps, and surges based on current and anticipated airborne aircraft at local and national levels. Traffic managers at the FAA Air Traffic Control System Command Center use TFMS tools to model and implement strategic traffic management initiatives across the NAS, maximizing the use of available capacity and minimizing delays.

TFMS mitigates issues, such as poor weather, that require proactive planning, coordination, and adjustments. Such mitigation is needed to lessen negative consequences of these constraints, which include delays, missed connections, canceled flights, and increased fuel consumption. When delays are unavoidable, TFMS allows each flight operator to submit the best route options and substitute flights to satisfy business objectives, for example, to ensure more passengers are on time to catch connecting flights.

Time Based Flow Management (TBFM)

TBFM uses time instead of distance to schedule and sequence aircraft. Compared to the miles-in-trail process for sequencing aircraft, in which controllers assign additional distance measured in miles between aircraft, TBFM provides a more efficient flow that reduces fuel burn, lowers emissions, and increases throughput.

TBFM, evolved from the legacy Traffic Management Advisor, is a system for planning flight trajectories through cruise altitude to the terminal approach airspace. Air traffic controllers can better regulate traffic by directing each aircraft to specific locations at a designated time. TBFM can sequence and schedule aircraft, taking into account aircraft types and

flight characteristics. It maximizes throughput at select busy airports and terminal radar approach control (TRACON) facilities without compromising safety. The system has been implemented and is available for operations at 20 en route centers.

TBFM departure management tools include:

- **Integrated Departure/Arrival Capability (IDAC)**, which automates the process of monitoring departure demand, identifying departure slots, and assigning them to aircraft. The tool coordinates departure times between airports and informs air traffic control towers so they can select from available departure times and plan their operations to meet those times. IDAC uses electronic messaging rather than a telephone call from the tower to the en route center to request a departure time.

- **En Route Departure Capability (EDC)** using IDAC automation helps determine how long to delay a flight departure and where it will fit in the overhead stream. EDC helps to manage a miles-in-trail restriction, when controllers require additional spacing between flights to manage congestion in another part of the country.

TBFM arrival management tools include:

- **Time-Based Metering**, which delivers aircraft to a specific point at a specific time. It allows air traffic controllers to manage aircraft in congested airspace more efficiently by smoothing out irregularities and delivering a more consistent flow of traffic.

- **Adjacent Center Metering and Extended Metering**, which take the metering capability beyond a single center's airspace. Aircraft can absorb delays by reducing cruise speed at more fuel-efficient altitudes to meet their scheduled time of arrival.

- **Ground-based Interval Management–Spacing (GIM-S)**, which is an interface between TBFM and ERAM that calculates speed advisories. Using GIM-S, an air traffic controller can put each aircraft at the correct time and place to initiate a STAR with an OPD more than 100 miles away from airports that support this PBN procedure. Aircraft improve fuel efficiency by absorbing delays at higher altitudes instead of following excessive step-by-step radar vectors for spacing closer to the airport.

Terminal Flight Data Manager (TFDM)

TFDM provides capabilities to manage surface operations and flight data at airports. This system results in four objectives: improved electronic flight data distribution and electronic flight strips in the tower; collaborative decision-making on the airport surface; traffic flow management integration with TFMS and TBFM; and systems consolidation. TFDM includes the functions of and replaces these tower systems: the Electronic Flight Strip Transfer System, Airport Resource Management Tool, Surface Management Advisor, and Departure Spacing Program.

In June 2016, the FAA awarded a contract to develop and deploy TFDM. Several precursor applications and testing of capabilities paved the way for better decision support tools for control towers and TRACON facilities.

- **Advanced Electronic Flight Strips (AEFS)** was the first prototype system of its kind in the NAS. Controllers use flight strips to keep track of flights. This technology is especially beneficial to controllers and air carriers when severe weather hits and changes to flight plans occur frequently. With AEFS, controllers can update flight information with a finger swipe or mouse click. Controllers no longer need to print new strips and physically carry paper flight strips across the control room. The AEFS function, which the FAA has implemented in towers at Charlotte

Douglas (CLT), Cleveland Hopkins (CLE), and Phoenix Sky Harbor (PHX) international airports, will be incorporated into the production TFDM system.

- **Surface Visualization Tool (SVT)** shares situational awareness of the airport surface for traffic management coordinators. Controllers at TRACON facilities can easily identify departure congestion and anticipate changes — such as switching runway operations in response to a shift in wind direction — as if they were in a tower. In 2017, the FAA enhanced SVT to include traffic flow management data, specifically gate assignment information that certain air carriers provide. SVT operates at 16 air traffic facilities to support early implementation of TFDM capabilities. The functions of SVT will be incorporated into and enhanced with deployment of TFDM.

- **Integrated Arrival/Departure/Surface (IADS) Traffic Management** improves the efficiency of surface operations at the nation's busiest airports through time-based metering of departures and improved sharing of non-sensitive flight operations information among various stakeholders.

Working with the FAA and industry on Airspace Technology Demonstration 2 (ATD-2), the National Aeronautics and Space Administration (NASA) is demonstrating the concept of an IADS capability that makes use of increased non-sensitive information sharing between the FAA and industry. The capability will deliver improved predictability and efficiency for scheduling and metering flights from airports. At Charlotte Douglas International Airport (CLT), ATD-2 Phase 1 introduced the tools and folded in the

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Benefits of

DSSs in the Operation

A joint FAA-industry team evaluated the impact of **EDC** and **IDAC** on departure delays for flights from New York to Atlanta, Charlotte, Philadelphia, and Washington, DC. They found a reduction of 1 minute, 12 seconds for flights bound for Hartsfield-Jackson Atlanta International Airport (ATL), for example. EDC and IDAC from New York-area airports is resulting in savings of $600,000 from fewer delays for routes to ATL.

Since the ATD-2 demonstration of the **IADS system** began in 2017

through January 31, 2020, NASA reported the first two phases of the project have provided these results for the airlines and the flying public:

- Aircraft burned 653,000 fewer gallons of jet fuel.

- Fuel savings prevented the release of carbon dioxide equivalent to 100,000 trees you would have to plant in an urban environment to offset that amount of emissions.

- Jet engines ran for 3,300 fewer hours, which can help increase engine life and lengthen time between scheduled maintenance.

- Surface delays were reduced by 550 hours, saving passengers time sitting on an idle aircraft.

participation of FAA air traffic control facilities. Phase 2 expanded the scope of the demonstration to include Atlanta en route center and new technical capabilities. Phase 3 focuses on coordinating air traffic departing from Dallas/Fort Worth International Airport (DFW) and Dallas Love Field (DAL). The two airports represent the broader challenge of managing air traffic over metropolitan areas with multiple airports close together. Phase 3 began in October 2019.

ATD-2 achieves the vision of the capabilities described in the concept of operations planned for the TFDM system. NASA has been transferring ATD-2 capabilities, benefits, and lessons learned to the FAA and industry to improve information sharing for our DSSs and enhance collaborative decision-making. These technologies will increase predictability in the air traffic system and enhance operational efficiency while maintaining or improving capacity. This process will lead to reduced environmental effects and better coordinated scheduling across the NAS.

TFDM development began in 2017 and is scheduled to expand to Phoenix next. Another 88 sites are set to be completed by 2028. All 89 sites will feature electronic flight strips and 27 locations will have surface time-based management capabilities.

System Wide Information Management (SWIM)

SWIM is an information-sharing technology that delivers the right information to the right people at the right time with far less expense and complexity than legacy methods. The FAA shares non-sensitive information on SWIM and other channels in accordance with our policy on protecting sensitive unclassified information. Sensitive information includes aviation security, homeland security, and protected critical infrastructure information. Before SWIM, the FAA primarily shared data through dedicated point-to-point computer connections and via radio, telephone, and the internet. With these conventional methods, everyone could not see the same information at the same time. This hard-wired infrastructure also could not readily support more data, systems, users, and decision makers.

SWIM eliminates the need for multiple computer interfaces to access data from different sources. With this new method, data producers publish the information once and subscribers access information through a single connection (Figure 3).

SWIM promotes situational awareness and more accurate aeronautical, flight, surveillance, and weather information. SWIM's common data format enables collaboration between the aviation community and governments worldwide. SWIM increases efficiency by allowing stakeholders to share current, relevant, reliable, and consistent information on demand, allowing for faster responses to changes in weather, traffic, and other factors. Today, 14 FAA programs and nine external organizations produce data for 80 services sent via the SWIM network. More than 600 consumers are registered to access the information, and the availability of data has created a new information ecosystem. Companies are using information derived from SWIM to develop innovative applications for the aviation community.

SWIM serves these types of consumers:

- The FAA, Department of Defense, and other government agencies
- Airlines that depend on SWIM for daily operations
- Large companies turning data into services for airlines
- Entrepreneurs seeking to develop innovative applications
- Foreign air navigation service providers
- Organizations or universities researching and developing future FAA programs

INTEGRATED INFORMATION MANAGEMENT

Before SWIM

With SWIM

The FAA

Airports · Airlines

Other Users
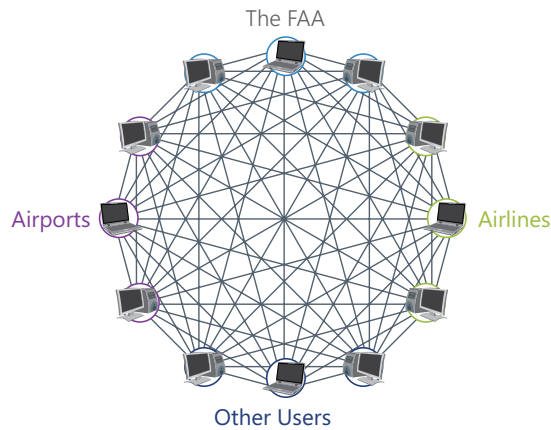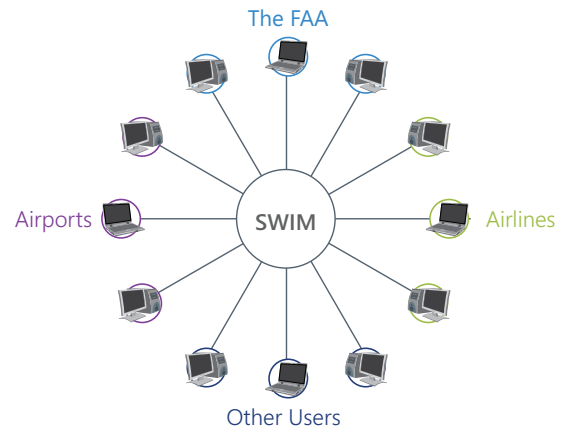
Figure 3: SWIM eliminates the need for multiple, point-to-point computer interfaces to access data from different sources. Instead, data producers publish information once and subscribers access the data through a single access point.

The FAA started SWIM in 2007 and has incrementally deployed applications as they became available. These features are examples of how SWIM is improving NAS operations:

SWIM Terminal Data Distribution System (STDDS)

STDDS converts raw surface and terminal surveillance data received through ADS-B, radar, or multilateration sensors into the extensible markup language, or XML, format. This format is nearly universal and can be easily combined into almost any application, allowing seamless data transfer now and into the future. STDDS uses the NAS Enterprise Messaging Service to send surface information from airport towers to the corresponding TRACON so traffic management coordinators can assess how to best balance demand with capacity. The FAA installed STDDS at 38 TRACONs that pull information from 150 airports. The data is available to internal and external NAS information consumers.

A new STDDS software release in 2019 enabled more non-sensitive data sharing.

Runway visual range is one of six sources from which STDDS publishes data. This tool measures horizontal distance a pilot can expect to see down the runway. Runway visual range is one of many legacy feeds that have switched to SWIM, and this data under SWIM has grown from 60 to more than 130 airports. It is expected to eventually serve 200 airports.

SWIM Cloud Distribution Service (SCDS)

SCDS enables the FAA to meet the needs of more users and more data flowing through the system. The cloud provides real-time, non-sensitive SWIM data to the public, including access to the same publicly available data offered via the NAS Enterprise Service Gateway.

A secure connection forwards approved data from the gateway to a commercial cloud provider using FAA Cloud Services. Instead of waiting at least 6 months to access data through the old registration and distribution process, the cloud enables a user to tap into tailored data within 72 hours of a basic online

Benefits of

Wake Recat in the Operation

A 2015 FAA performance assessment showed departure and arrival capacity increased after implementation of **Wake Recat** at the first four authorized locations: Cincinnati/Northern Kentucky (CVG), Hartsfield-Jackson Atlanta (ATL), Louisville Muhammad Ali (SDF), and Memphis (MEM) international airports.

- At CVG, SDF, and MEM, the average peak quarter-hour throughput increased by at least one departure and up to one arrival per runway.

- One runway at ATL increased by about two arrivals and two departures per hour.

- MEM experienced the highest increase in peak throughput, equivalent to 13 additional operations per hour.

- Taxi-out times were reduced, saving 86,000 minutes at ATL, 22,000 minutes at SDF, and 148,000 minutes at MEM from the beginning of the Wake Recat deployment in 2012 through the end of fiscal year 2014.

Additionally, a joint FAA-industry analysis in 2017 estimated $4.4 million in savings annually attributed to Wake Recat for four airports: Charlotte Douglas (CLT), Chicago O'Hare (ORD), Indianapolis (IND), and Philadelphia (PHL) international airports.

account setup. Operating costs are lower, and the new service adjusts bandwidth to support data flow.

Other Improvements

Not all NextGen improvements need expensive infrastructure. Sometimes research leads to new FAA policies, procedures, and standards that improve efficiency or increase capacity.

Wake Recategorization (Wake Recat)

A plane flying too close behind another is at an increased risk of a potentially dangerous encounter with wake vortex turbulence. To reduce wake-related hazards, controllers traditionally separated aircraft based on wake separation standards set on their maximum certified gross takeoff weight. Although safe, these separation standards did not take into account other aircraft characteristics, such as speed

and wingspan. Research provided better data on the strength of the wake and an aircraft's reaction to turbulence generated by aircraft in front of it. It provided an opportunity to generate new standards.

Wake Recat can increase airport capacity, which means more aircraft can take off and land, reducing arrival delays and wait times on taxiways and runways. The FAA is planning to deploy consolidated wake turbulence standards to all airports in the coming years to further enhance efficiency.

Improved Approaches and Low-Visibility Operations

Expanded Low Visibility Operations (ELVO) was a low-cost infrastructure program designed to reduce ceiling and runway visual range minimums through a combination of ground equip-

ment and procedures. It addressed limitations of low visibility and poor weather and allowed aircraft to operate at airports during inclement weather when they would have previously not been able. A 2015 FAA assessment showed access during low-visibility conditions of airports studied improved in two ways, in part, because of ELVO: No-access periods decreased by about 6 percent, and 17 percent more flights could land.

Besides ELVO, the FAA published amended rules to expand the use of Enhanced Flight Vision Systems (EFVS). An EFVS provides a means to display a real-time image of the external scene by using imaging sensors. Operators may use this image in lieu of the natural vision requirements when conducting an EFVS operation. The use of an EFVS may allow a pilot to fly instrument approaches in lower visibilities than they could using natural vision, increasing efficiency and throughput at many airports in the NAS.

Additionally, the FAA has conducted research and enabled operations using Synthetic Vision Guidance Systems (SVGS), which decrease pilot flight technical error and enable a more efficient transition to the visual portion of an instrument approach procedure. An SVGS combines flight guidance information with a database derived image to accurately depict the external scene. Display components provide the pilot with a dynamic perception of position, trend, and motion, which can facilitate the pilot's transition to natural vision references in low-visibility conditions.

NextGen Benefits

Our reporting of NextGen performance captures qualitative and quantitative benefits of implemented capabilities that focus on safety, throughput, and efficiency. FAA estimates of NextGen benefits are divided into achieved and future benefits from deployed and new capabilities.

CUMULATIVE BENEFITS OF EARLY NEXTGEN IMPROVEMENTS

Increased capacity with Wake Recat

More efficient operations through initial TBFM

Reduced flight time through improved routes

More efficient communication through Data Comm tower service

Fuel savings with Metroplex, OPDs, and others

Legend: Communications, Navigation, and Surveillance · Automation · Separation
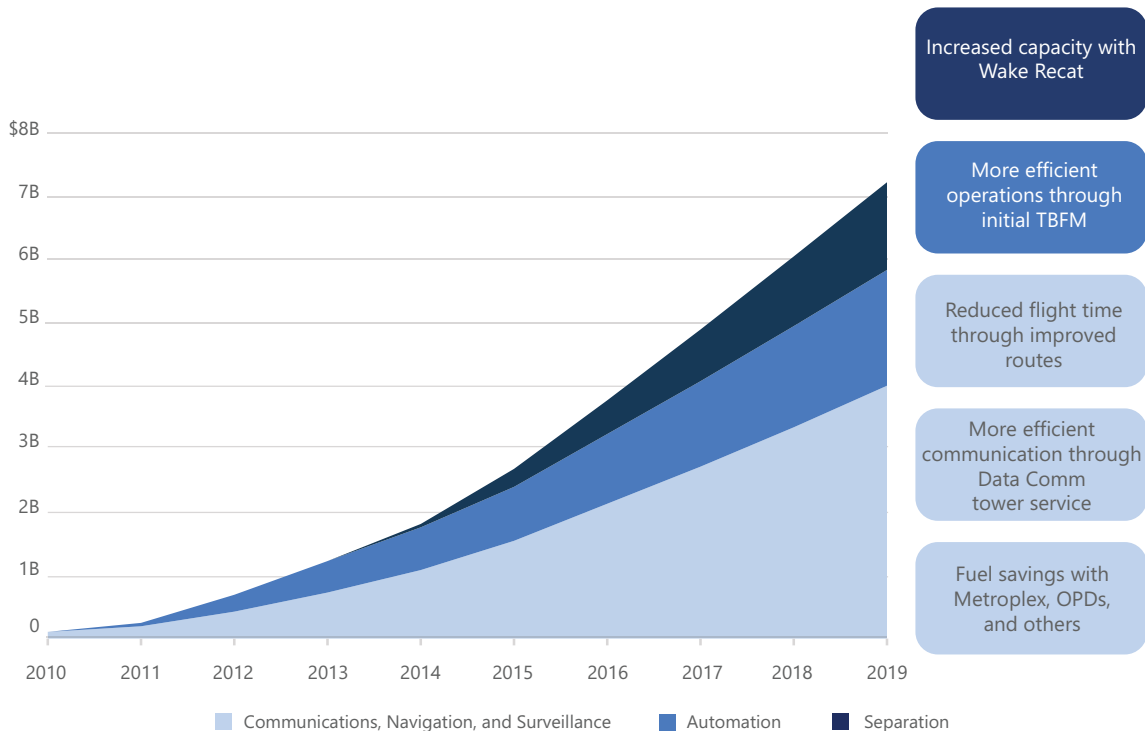
Figure 4: Early implementation of select technologies is already providing value for the aviation community, exceeding $7 billion between 2010 and 2019.

Measuring Early Benefits

Between 2010 and 2019, implemented NextGen capabilities accrued more than $7 billion worth of benefits divided into these categories (Figure 4):

- **Reduced accidents:** 5 percent

- **Fuel savings:** 17 percent

- **Other aircraft operating cost savings:** 21 percent

- **Passenger travel time savings:** 57 percent

We calculate these benefits by analyzing performance before and after implementation of NextGen capabilities. Beginning in 2016, many of these analyses were conducted in partnership with industry through the Joint Analysis Team (JAT). The NextGen Advisory Committee (NAC) formed the JAT, which is committed to jointly evaluating the benefits of implementing specific capabilities in the NextGen Priorities Joint Implementation Plan at select locations. Through various JAT, FAA, and industry analyses, we learned that NextGen improvements have resulted in:

- **Increased capacity**: Wake Recat increased throughput from 1-20 percent, depending on specific fleet mix at each airport.

- **Efficient operations**: TBFM reduced departure times and the negative effect of separating traffic by miles-in-trail.

- **Reduced flight time**: Navigation improvements, such as ELSO and Q-Routes, saved on average more than 2 minutes per flight.

MAXIMIZING NEXTGEN BENEFITS
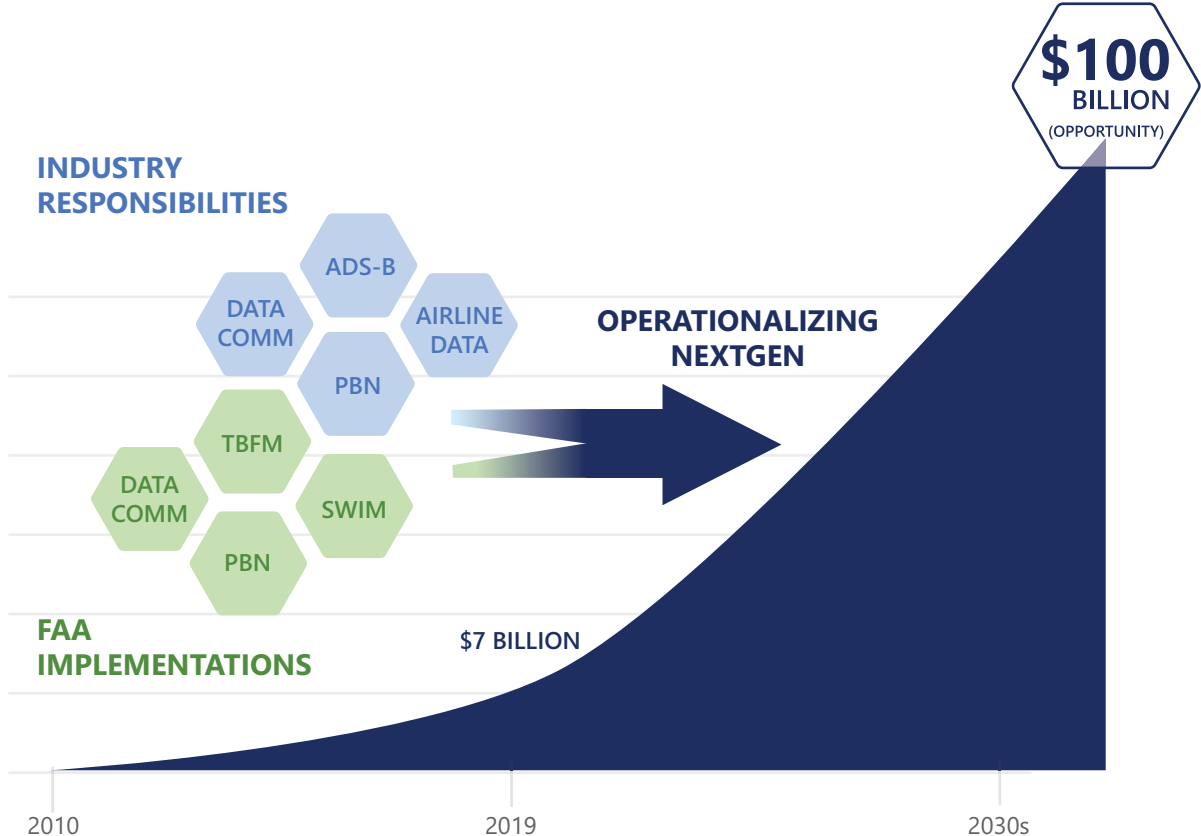
Figure 5: Benefits from NextGen have the potential to grow from $7 billion in 2019 to $100 billion by the early 2030s through FAA implementations and industry equipping aircraft and training crews.

- **Efficient communications**: Data Comm Tower Service saved on average nearly 1 minute of gate and taxi time per equipped flight.

- **Fuel savings**: OPDs and Metroplex saved nearly 115 million gallons of fuel from 2010 to 2019.

- **Reduced accidents**: ADS-B In in Alaska prevented on average 20 accidents per year.

We continue to work with industry to form consensus on the data, methodologies, and value of NextGen enhancements. This work influences how we prioritize future implementations. Achieved benefits so far represent a portion of expected total benefits. As programs continue to capitalize on the deployed NextGen infrastructure, the FAA expects benefits to grow.

Future Benefits

We estimate that the benefits from the NextGen capabilities currently in place will deliver an additional $15 billion between 2020 and 2030. Overall, NextGen benefits can increase to $100 billion through the early 2030s as the FAA makes advanced technologies available at more locations and industry increasingly equips aircraft to use the technologies and share data (Figure 5). This amount represents the combination of realized benefits from implemented capabilities projected through 2030, and modeled benefits for future capabilities that have not yet been deployed.

The COVID-19 public health emergency that began in early 2020, and its effects on aviation and the broader economy, is unprecedented. Much uncertainty remains on how the public health emergency will affect NextGen milestones, industry commitments, and projected benefits. We have not accounted for the impact in this report. ✈

The FAA is working toward our vision of managing air traffic more strategically through Trajectory Based Operations.

OPERATIONALIZING NEXTGEN
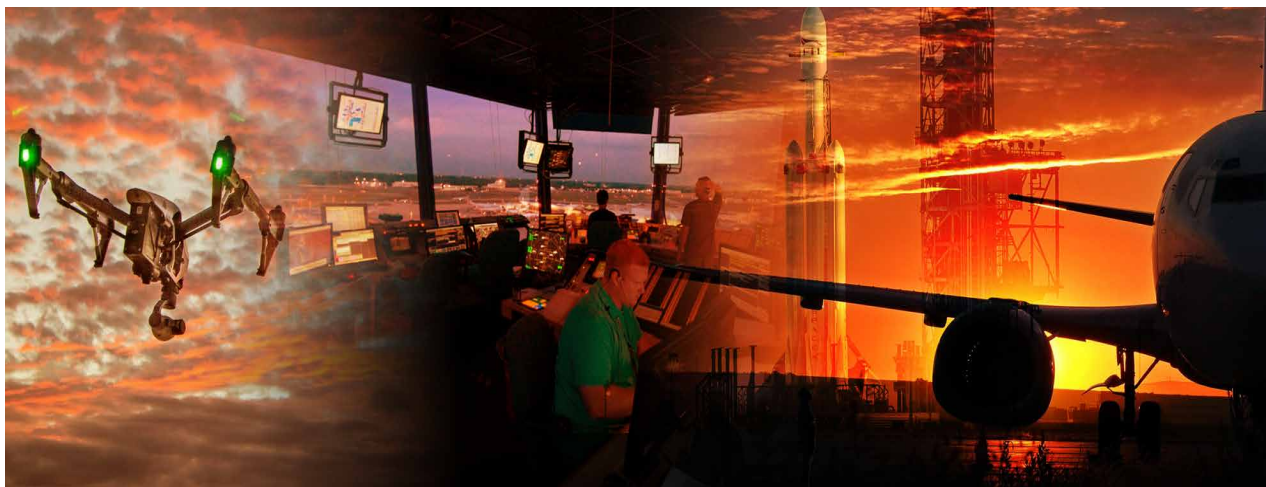
With the fundamental NextGen infrastructure in place, we plan to improve how we use existing capabilities while introducing other innovations to realize a greater return on investment. The next step is operationalizing NextGen. Operational integration with aircraft and air traffic management systems, pilots and air traffic controllers, and decision support systems and human interface activities is necessary to transform the National Airspace System (NAS) to enable Trajectory Based Operations (TBO).

Leveraging Infrastructure

The Federal Aviation Administration (FAA) is using knowledge gained since 2011, when we published the NextGen Mid-Term Concept of Operations, to form NextGen. We deferred six concepts with too high of a technical risk, such as those with no available technical solution. As capabilities mature and the infrastructure is transformed to support the new concepts, we will implement additional improvements. The following are some of the initiatives that will arrive in the next 10 years.

Data Communications (Data Comm) En Route Services

In November 2019, the FAA began implementing Data Comm initial en route services. Completion at all 20 of the air traffic control facilities that manage air traffic at the en route phase of flight is expected in 2021.

Initial en route services build upon the departure clearances offered by tower service. Controllers and pilots have multiple types of messages they can exchange, such as initial check-in and transfer of communications as aircraft enter and exit en route sectors, and reroutes. After initial en route services, full en route services are scheduled to start in 2022. More types of messages will be available, including advisory messages and holding instructions.

Beginning in 2025, enhanced services will provide additional capabilities to maintain flow-through or increase capacity in constrained airspace. For instance, a message to pilots to temporarily divert from and extend their flight path, known as path stretch, could be sent to keep aircraft on schedule when speed changes are insufficient.

Performance Based Navigation (PBN) Ground Infrastructure

The FAA will use PBN to right-size the navigation assets in the NAS through our review of procedures and infrastructure to determine if they are still useful or should be removed. The FAA provides PBN capability and resiliency during potential Global Navigation Satellite System disruptions. We are expanding coverage of distance measuring equipment area navigation, known as DME/DME RNAV, by installing more than 120 DME facilities. We anticipate completion of en route coverage in 2022 and terminal coverage by 2031.

The FAA is also maintaining a minimum operational network of Very High Frequency Omnidirectional Range (VOR) stations while reducing the legacy VOR infrastructure in the contiguous United States by approximately 34 percent, discontinuing the navigation service for about 300 VORs by 2030.

Automatic Dependent Surveillance–Broadcast (ADS-B)

Deployed ADS-B infrastructure can be used to achieve future operational benefits, including:

- **Reduced Separation:** ADS-B enables a reduced separation standard of 3 nautical miles in selected en route airspace, which increases NAS efficiency and capacity for commercial operators.

- **ADS-B In Applications:** ADS-B In brings the opportunity to implement a growing number of applications to increase NAS spacing efficiency. These applications include Enhanced Air Traffic Services, Cockpit Display of Traffic Information Assisted Visual Separation, and Advanced Interval Management.

- **Conflict Detection:** More accurate surveillance data from ADS-B Out provided to automation equipment will decrease the number and magnitude of conflict predictions, which reduces vectoring and fuel consumption.

- **Search and Rescue:** ADS-B coverage is often available at lower altitudes than radar. The availability of high-accuracy, high-update rate surveillance information makes it easier to find an accident site. Faster rescues mean more lives saved.

- **Radar Divestiture:** Overlapping ADS-B and legacy radar coverage gives the FAA opportunities to right-size surveillance infrastructure across the NAS.

Industry Responsibilities

While the FAA has modernized the aviation infrastructure for NextGen and is continuing to deploy new procedures and technologies, aviation industry participation and follow-through with commitments are just as important to the full potential of NextGen.

The NextGen Advisory Committee (NAC) identified mixed aircraft equipage as a primary risk for full realization of NextGen benefits. Mixed equipage describes an operating environment where the differing capabilities of aircraft flying in the same area prevent operators from taking full advantage of modern air traffic management methods, such as TBO.

The NAC collaborated with the FAA to develop a minimum capabilities list (MCL) to define optimal aircraft equipage levels. The MCL is intended to provide instructions for forward-fit aircraft equipage across the NAS and to maximize return on investment for the FAA and airspace users.

The NAC also identified a set of supplemental capabilities that may be beneficial to some operators depending on individual business cases and operations. The FAA looks forward to the adoption of the MCL to inform future aircraft purchases and upgrades so that industry and the FAA can maximize NextGen benefits.

Trajectory Based Operations

Operational integration is necessary to achieve TBO, the long-term goal of NextGen. TBO is an air traffic management method for strategically planning, managing, and optimizing flights throughout the operation. It relies on information exchange between air and ground systems, the aircraft's ability to fly precise paths, and time-based management. PBN and time-based management comprise a four-dimensional trajectory of latitude, longitude, altitude, and time.

TBO results in a unified flow that will improve predictability, efficiency, throughput, and flexibility (Figure 6), as detailed below:

- **Predictability**: Traffic managers can proactively manage and resolve congestion problems. Consistent and reliable schedule and travel times provide operators more opportunities to better decide on fuel loads and how to manage the fleet.

- **Efficiency**: Predictable schedules enable flights to accept delays where the engines burn less fuel, either on the ground or in the air. Data Comm and Decision Support Systems for traffic flow will allow fast rerouting. Increased use of PBN saves fuel and cuts flight distance.

- **Throughput**: Air traffic controllers and managers can much better estimate where an aircraft will be along its flight path. These estimates improve the ability to plan and more accurately produce an integrated schedule for traffic demand to maximize the number of aircraft that can move through the airspace and at the airport.

- **Flexibility**: Air carriers and the FAA can work together more to determine operator trajectory preferences and customize solutions that best meet business objectives.

IMPROVEMENTS WITH TBO

Predictability
Decrease variability in block times[+] and increase schedule adherence

Flexibility
Users can specify operational prioritization of flights

Integration
Information Sharing*
Ground and Flight Deck Automation
Trajectory Based Operations = PBN+TBM
Air Traffic Training
Air Traffic Procedures
Change Management

Flight Efficiency
Distribute delay at more efficient phase of flight, reduce delay

Throughput
Manage more aircraft going in/out of airport through increasing capacity and improving use of existing capacity

PBN = Performance Based Navigation | TBM = Time-Based Management

*The FAA shares information in accordance with our policy on protecting sensitive unclassified information.

[+]Block times start when aircraft leave the departure gate and end when they arrive at the destination gate.

Figure 6: Operational integration across NextGen technologies, more connected systems, and trained employees are essential to capturing TBO's operational improvements in predictability, efficiency, throughput, and flexibility.

TBO leverages NextGen investments already made in communications, navigation, surveillance, automation systems for decision support, and flight data management and non-sensitive information sharing. The vision for TBO in 2025 will be accomplished through improved air traffic management strategic planning initiatives along with the predominant use of time-based management and PBN.

Phases of TBO

The FAA is implementing TBO in four phases:

- **Infrastructure** deployment of foundational automation, surveillance, weather, and information and data exchange infrastructure to support TBO enabling capabilities and products.

- **Initial TBO** capabilities deployed for use domain by domain with integration of the capabilities left to the human operator.

- **Full TBO** capabilities delivered to all domains, providing the ability to automate the integration of time-based management data and tools to greatly improve strategic planning and execution.

- **Dynamic TBO** will use advanced aircraft and ground automation to enable flight-specific time-based solutions for reroutes and advanced flight-specific TBO to further optimize operations.

Initial Trajectory Based Operations

Initial TBO (iTBO) begins to integrate NextGen operational changes and capabilities for a specific geographic area. This strategy ensures facilities receive the right capabilities for their needs in the right sequence and at the right time. Training and change management are also in focus.

The FAA selected the Northeast Corridor, the nation's busiest airspace, which spans the area from Boston to Washington, DC, as the first region for iTBO. Congestion and delays in the Northeast Corridor affect the entire country,

making the region a strategically important place to start iTBO. We also selected this region after comparing costs, benefits, opportunities, and risks with other NAS operating areas.

Our choice of this region also supports industry priorities. The FAA plans to increase arrival capacity during periods of low visibility for Philadelphia International Airport (PHL), improve departures out of the New York area during poor weather, and deploy other key functions for iTBO. The next deployment of iTBO will extend to the Northwest Mountain (Denver focus) and Mid-Atlantic (Atlanta focus) regions.

Beyond iTBO

The transition to Full and Dynamic TBO will be evolutionary. TBO benefits will gradually increase over time as the FAA, partner agencies, and aircraft operators gain more experience and as TBO is further implemented across the nation. With Dynamic TBO, information will be integrated and further shared to improve NAS operations.

Change Management

TBO is an operational change that will require new skill sets for controllers, traffic managers, pilots, and dispatchers. The FAA has developed a change management plan focused on five key areas: leadership mobilization, stakeholder engagement, communication, training/education, and organization/workforce alignment. A holistic, human-centric approach is needed to promote new skill sets needed for TBO while employees stay proficient with the use of conventional techniques.

We are evolving from air traffic control operations that are loosely integrated with strategic traffic management planning and decision support to more tightly coupled strategic and tactical operations through predominant use of time-based management. Air traffic controllers and traffic managers need to be trained on how to develop and execute an optimal TBO

plan. The FAA will incorporate traffic management and TBO training at the FAA Academy so that entry-level air traffic controllers can begin to develop an awareness of these skills. We will also invest in new integrated training simulators at the academy and in the field where our employees can build their skills. ⤴

NextGen will accommodate new users and emerging technologies that contribute to our nation's economic growth.

ACCOMMODATING ALL OPERATIONS

NextGen is flexible to incorporate changes. The Federal Aviation Administration (FAA) is working with industry and academia to ensure that new operations and new products like these will be safely incorporated into the National Airspace System (NAS). We anticipate continued rapid growth in unmanned aircraft systems (UAS), also known as drones, and space launch and re-entry operations. Remote towers, new aircraft materials, alternative jet fuels, unleaded aviation gasoline, and advanced cybersecurity are also being tested.

Unmanned Aircraft Systems

UAS, also known as drones, refer to aerial vehicles operated by a pilot on the ground. Drone operations continue to rapidly expand in number and complexity. This growth is not only affecting UAS platforms and technologies, it is also impacting the airspace system and supporting services in which they operate.

In the past, pilots requested permission and controllers cleared a large area of airspace for drones to operate, which is an inefficient use of airspace and limits how many UAS can fly in a given area. The FAA vision for full integration of UAS into the NAS goes beyond simply segregating drones from other aircraft. It involves UAS operating harmoniously alongside manned aircraft, and applying many of the same air traffic management procedures in place for conventional aircraft.

NextGen assists in enabling drone operations in the NAS without disrupting or delaying traditional aircraft operations. We are incrementally updating FAA policies and procedures to provide UAS with:

- Airspace access when operating beyond visual line of sight

- Communication with air traffic controllers

- Detect and avoid capability

- Advisory information

- Flight information management

UAS Traffic Management (UTM)

UTM is an ecosystem for operations not served by air traffic control that is separate from but complementary to the FAA air traffic management system. UTM services are targeted toward operations of UAS at flight levels below 400 feet. Unlike operations in controlled airspace, we envision UTM to be a community-based traffic management system, where operators are responsible for managing flights based on rules established by the FAA. The FAA, in partnership with the National Aeronautics and Space Administration (NASA), defined the innovative industry-regulator UTM architecture that includes industry's UAS Service Supplier (USS). Under this arrangement, the USS acts as an entity that assists UAS operators with meeting UTM operational requirements and helps drone operators plan and manage their flights safely.

UTM is founded on layers of information sharing and exchange, from operator to USS, USS to USS, and USS to the FAA. UAS pilots share their flight intent with each other and coordinate to de-conflict and safely separate trajectories. The FAA has on-demand access to UTM operational information. In this low-altitude airspace, operators and USS will communicate through a network of highly automated systems instead of pilots and air traffic controllers communicating by voice. UAS operators and USSs would be responsible for safely managing flights without FAA interaction.

UTM Pilot Program (UPP)

UPP, a partnership between the FAA, NASA, industry, and academia, is responsible for developing, demonstrating, and supporting initial UTM operations. Researchers will provide technical specifications, functional prototypes, and field-testing data for safety analysis. As an initial step in completing the UPP demonstrations, we tested the NASA-developed prototype Flight Information Management System (FIMS). FIMS provides an interface for data exchange between FAA systems and UTM users, enabling the exchange of airspace constraint data between the FAA and the USS network. The FAA also uses this interface to access information on active UTM operations, to include operations intent, status, and dynamic restrictions managed by a USS. In 2019, the FAA, NASA, and industry partners successfully completed the first phase of UPP demonstrations, including demonstrations with live UAS flights combined with simulated UTM operations at three UAS test sites. Each test successfully exhibited key UTM capabilities. A second phase of demonstrations is underway.

Urban Air Mobility (UAM)

The FAA and aviation community are exploring the feasibility of more autonomous manned and unmanned air cargo and passenger vehicles traveling at lower altitudes over urban and metropolitan areas. This UAM concept has already attracted research and demonstrations, including the NASA Advanced Air Mobility National Campaign, to evaluate technical solutions that feed into the FAA UAM concept.

To safely incorporate these types of users into the NAS, the FAA must review and refine, or develop through supporting research, air traffic requirements, policies, and procedures. We are working with NASA and industry to describe the UAM operational environment. The concept development will consider introduction of new aircraft types with increasing level of autonomy, interactions with the air traffic management system, and the role of cooperative traffic management concepts explored in UTM.

Upper Class E Traffic Management (ETM)

Feedback from stakeholders confirmed an increased demand for unmanned free balloons, airships, supersonic aircraft, and sophisticated high-altitude and long-endurance aircraft. These opportunities present challenges for the current airspace infrastructure and management model, which cannot cost effectively meet the needs of the envisioned upper

Class E airspace environment above 60,000 feet. The FAA is working with NASA and industry to develop the concept of operations for ETM, which will guide future policies, regulations, services, and infrastructure required to support safe and efficient operations in that airspace. We envision a cooperative air traffic management environment in upper Class E airspace, where operators are responsible for coordinating and executing their diverse operations.

Space Operations

As space launch and re-entry operations increase across the United States, the FAA is reviewing how to efficiently accommodate them. The FAA's approach to integrating space operations into the NAS is evolutionary and will mature and refine over time. We have already made significant progress by improving operational procedures and processes, such as time-based launch procedures and dynamic launch/re-entry windows to help gain efficiencies across the NAS.

Based on lessons learned from the NASA space shuttle program, the FAA realized it needed to more accurately model a launch or re-entry vehicle malfunction, better identify potentially affected airspace and assess its effect on air traffic, and quickly distribute information to those who need it. Today, the FAA Joint Space Operations Group (JSpOG) gathers operational data about each launch and re-entry in real time. The group also coordinates with multiple offices and air traffic facilities to adapt airspace usage with space operations.

The Space Data Integrator (SDI) operational prototype is an initial, foundational automation step for the FAA to integrate space into the NAS. SDI will provide automation to improve the current operation. SDI will receive data on launch and re-entry vehicle status gathered from sources such as spaceports and spacecraft operators. The system will process and display the data, and distribute it to the Traffic Flow Management System (TFMS).

SDI will allow the FAA to track the actual versus planned trajectories of launch and re-entry operations, provide status of mission events, and display aircraft hazard areas (AHA). AHAs identify airspace in the spacecraft's trajectory that could contain falling debris. The current FAA tool that computes AHAs in real time takes several minutes to complete its computation. SDI will send vehicle position and hazard area information to TFMS, which collects information about actual and planned air traffic operations. Using TFMS will improve JSpOG's situational awareness of how the space mission affects broader NAS operations. With SDI as a strategic decision support tool coupled with procedural enhancements, the FAA will begin to reduce the extent and duration of closed airspace as the space mission progresses and respond effectively to contingencies.

Since 2019, the FAA has also focused on needed tactical improvements for existing NAS automation systems to integrate space operations. In 2020, NextGen research culminated in the demonstration of the technical feasibility of receiving space-operator-generated airspace hazard volumes for display on the En Route Automation Modernization platform in real-time during an actual launch. The project also identified data flows and developed a space information data capture and storage capability with playback features. Furthermore, it allowed for a unique opportunity to successfully demonstrate public-private partnership by bringing government and industry together to prove this concept.

The next step is to improve mission planning tools by integrating new capabilities into existing NAS systems. If a vehicle malfunctions during a space operation, the corresponding AHA could extend across multiple air traffic facility boundaries. This spread could affect aircraft within and approaching the area. New decision support technology will help the FAA employ risk-based decision-making to identify which aircraft are affected and how to best mitigate the risk. NextGen technologies may help expedite data and information distribution.

Remote Towers

Remote towers provide air traffic services from a facility that may not be on or near the airport by controllers using a visual depiction of that airport and surrounding airspace. They are expected to provide the same services as traditional airport traffic control towers and could potentially be used as a cost-effective alternative to a traditional federal contract tower. Remote towers could help maintain safety and efficiency at these airports.

Remote towers may feature enhanced capabilities, such as color cameras with pan-tilt-zoom and night vision features. They may also include automated identification and display of aircraft and other information on video monitors.

As part of the FAA's business case evaluation for remote towers, we are testing the technology at Leesburg Executive Airport (JYO) in Virginia and Northern Colorado Regional Airport (FNL) in Loveland. We established a draft advisory circular describing initial standards for a visual remote tower system operating in similar airport layouts. The FAA plans to select more sites to validate the process in the circular and explore how this capability can be expanded to more complex airports.

Environmental Footprint

The FAA shares research and development costs to make environmental investments more attractive to our industry partners. The work supports a NextGen goal of reducing the environmental impact of aviation while sustaining growth. The aviation community is working together to develop alternative fuels and certifiable aircraft and engines that produce less noise and emissions and increase fuel efficiency.

New Technologies, Alternative Fuels

The Continuous Lower Energy, Emissions, and Noise (CLEEN) program is the FAA's main environmental effort to accelerate the develop-

A member of the remote tower evaluation team points to an aircraft on a video depiction of Leesburg Executive Airport, where the FAA is testing a remote tower.

ment of new aircraft and engine technologies and advance sustainable alternative jet fuels.

Technologies matured during CLEEN's 2010–2015 phase will reduce fuel consumption by 2 percent from 2025 through 2050 across the domestic fleet, according to research conducted at the Georgia Institute of Technology. This figure is equivalent to saving 22 billion gallons of jet fuel; the reduction in carbon dioxide emissions is comparable to removing 1.7 million cars from the road. CLEEN will save airlines $2.75 billion per year and contribute to a 14 percent decrease of geographical areas exposed to noise.

Alternative jet fuels are another element of the FAA strategy to address aviation's environmental and energy challenges. These resources can replace petroleum-derived jet fuels without the need to modify engines and aircraft. We are now focusing on testing the safety of these alternative fuels and analyzing processes to understand benefits, production potential, and challenges to establishing supply. Since 2006, the FAA has worked with the alternative jet fuel stakeholder community through CAAFI, the Commercial Aviation Alternative Fuels Initiative. We also are partners with other federal agencies, universities, and research institutes to accelerate testing of alternative jet fuel required for certification. These efforts happen largely through CLEEN and the FAA Center of Excellence for Alternative Fuels and Environment.

Unleaded Aviation Gasoline

Leaded aviation gasoline used to fuel piston engine aircraft is the largest contributor to lead emissions in the United States. The FAA William J. Hughes Technical Center is researching suitable alternatives. We originally hoped for a fuel replacement that would not require modifications to existing engines, but extensive research determined it was

not feasible. In response, the FAA started investigating ways to lessen the impact of implementing replacement fuel on the general aviation fleet and on manufacturing and distribution infrastructure. Once a suitable unleaded alternative is approved, the FAA and the aviation community will collaborate to safely transition to this new fuel.

Cybersecurity

The increasingly interconnected NAS presents new cybersecurity challenges. While cyberthreats are many and constantly evolving, so are technologies and research and development that can resolve these challenges. The FAA is exploring how to use the latest resources available to combat cyberthreats by examining emerging capabilities, such as artificial intelligence, machine learning, self-adapting architecture, and big data analytics. Guaranteeing cyber resilience will mean taking a fresh look at how the overall NAS behaves under sustained malicious actions by well-equipped adversaries.

The FAA William J. Hughes Technical Center is our hub for cybersecurity research. The Cybersecurity Test Facility provides research and evaluation services to strengthen information security across our organization. Its main capabilities include vulnerability assessments, penetration testing, cyberexercises and training, enterprise security support, and security tool evaluations and capability modeling. We also collaborate with other government agencies. Between 2016 and 2018, the FAA partnered with the Defense and Homeland Security departments on the Aviation Cyber Initiative's vulnerability testing of civil aircraft. ✈

GOING BEYOND NEXTGEN

The mission of the Federal Aviation Administration (FAA) is to provide the safest, most efficient aerospace system in the world. The aviation industry and flying public are experiencing benefits from takeoff to landing as a result of NextGen. Airspace modernization reflects our commitment to continually strive to improve the safety and efficiency of flight in this country and demonstrate global leadership in how we safely integrate new users and technologies into our aviation system. We will continue to work with our partners in the aviation industry to advance NextGen. Modernization should never stop, thus, we look beyond NextGen to see how we should adapt our strategies to accommodate increasing air traffic, expanding markets, changing technology, cybersecurity, and data sharing needs.

The operators of the future NAS will require tools that increasingly rely on satellite communication, digital data, automation, artificial intelligence to support decision-making, cloud infrastructure, and even more integrated information. The aviation community is already collaborating on developing the vision for the operating environment beyond NextGen, and we will share new concepts with our stakeholders early to allow the community to participate in building that future NAS.

Other Resources

Ongoing implementation of NextGen will support continued economic growth. Through a continuous rollout of improvements, NextGen builds upon its capabilities and benefits. More information about programs, portfolios, and technologies introduced in this document are found in these resources:

- **NextGen Implementation Work Plan Through 2025** (Appendix A) describes the operational improvements and associated capabilities within the 11 NextGen portfolios, including benefits and implementation timelines through 2025.

- **Return on Investment Report** (Appendix B) summarizes the return on investment of major NextGen programs and lists the five NextGen Joint Priorities focus areas.

- **FAA's NextGen webpage** (faa.gov/nextgen) provides additional information on our airspace modernization initiatives. ✈

APPENDIX A:

NEXTGEN IMPLEMENTATION WORK PLAN THROUGH 2025

APPENDIX A:
NextGen Implementation Work Plan Through 2025

Appendix A describes how the FAA plans to modernize the National Airspace System (NAS) through the Next Generation Air Transportation System (NextGen) initiative. The appendix summarizes the structure that our project planners and engineers use to effectively implement NextGen. It also documents the milestones to deliver operational improvements to the NAS. Detailed work plans describe the improvements and include high-priority, ready-to-implement activities to deliver benefits for all airspace users.

This appendix contains:

- Descriptions of the NAS Enterprise Architecture, NAS Segment Implementation Plan, NextGen portfolios, and NextGen priorities

- A detailed work plan by NextGen portfolio showing joint commitments through 2021 and increments through 2025

- A roadmap to Trajectory Based Operations (TBO)

NextGen is the FAA's comprehensive overhaul of the NAS. It is enabling operational improvements and enhancing services to the aviation community. Most notably, NextGen is transitioning the NAS to TBO, an air traffic management method for strategically planning, managing, and optimizing flights throughout the operation.

The FAA has delivered the foundational elements of NextGen with support from federal agency partners and the aviation community. These capabilities are already benefiting aviation stakeholders and travelers through reduced operating costs and time savings. The FAA plans to complete the implementation of the major components of NextGen by 2025.

Architecture and Implementation

To identify how to transform the NAS, the FAA built the NAS Enterprise Architecture (EA), which describes the evolution of air traffic control through our implementation of new services, technologies, and infrastructure. It documents current and future mission-critical and mission-support systems. The EA also contains roadmaps to help guide identification, tracking, and maturation of concepts that will further advance the NAS.

The EA helps us transform the NAS by clearly communicating system responsibilities while enhancing NAS operations. This architecture eases how we consolidate functions and systems while continuing to satisfy the aviation community's changing needs.

Functions of the EA include:

- Providing a common reference for the FAA to make informed investment decisions

- Aligning aviation systems and technologies we use as an air navigation service provider with the agency's mission

- Helping to identify duplication of effort, show interoperability, and increase efficiency

Supporting the NAS EA is the NAS Segment Implementation Plan (NSIP), our blueprint for developing, integrating, and implementing NextGen capabilities. The NSIP provides the framework for understanding interdependencies among operational improvements, increments, systems, and investment decision points. The FAA defined 5-year segments to assist in planning these investments. Figure A-1 defines the segments and

BUILDING THE FUTURE

Segment			
Alpha 2010–2015	**Bravo** 2016–2020	**Charlie** 2021–2025	**Delta** 2026–2030
Overall NextGen Transformation			
Foundational Infrastructure	**Expanding Capabilities**	**Realizing NextGen / Leveraging NextGen**	
The Alpha timeframe can be considered the foundational infrastructure phase of NextGen.	The Bravo period focuses on expanding capabilities and improving the infrastructure laid out in the Alpha period.	The Charlie and Delta periods are for capabilities that require additional maturation or concept development. These are future, and in some cases, near-term capabilities that will benefit the NAS in terms of safety, efficiency, predictability, and flexibility.	
Trajectory Based Operations Phases			
Infrastructure	**Initial**	**Full**	**Dynamic**
Deployment of foundational automation, surveillance, weather, and information and data exchange infrastructure to support TBO enabling capabilities and products.	Initial TBO capabilities deployed for use domain by domain with integration of the capabilities left to the human operator.	Full TBO capabilities delivered to all domains, providing the ability to automate the integration of time-based management data and tools to greatly improve strategic planning and execution.	Dynamic TBO will use advanced aircraft and ground automation to enable flight-specific time-based solutions for reroutes and advanced flight-specific TBO to further optimize operations.

Figure A-1: NextGen transformations and TBO phases align to one of four 5-year time segments.

the corresponding NextGen transformations and TBO phases for each time period.

The NSIP serves important, distinct purposes for different NAS users. Program managers, engineers, and acquisition teams use the resource to plan NextGen milestones. External stakeholders, such as advisory organizations, use the plan to identify and prioritize capabilities.

NextGen Benefits

Improvements from new technologies, capabilities, and procedures covered in the NSIP provide primary and secondary benefits in one or more of these areas:

- **Access and Equity**: Provides an operating environment that ensures that all airspace users have right of access to the air traffic management (ATM) resources needed to meet their specific operational requirements and that the shared use of airspace by different users can be achieved safely. The global ATM system should ensure equity for all users that have access to a given airspace or service. Generally, the first aircraft ready to use the ATM resources will receive priority

except where significant overall safety or system operational efficiency would accrue, or national defense considerations or interests dictate that priority be determined on a different basis.

- **Capacity**: Exploits the inherent capacity to meet airspace user demands at peak times and locations while minimizing restrictions on traffic flow. To respond to future growth, capacity must increase, along with corresponding increases in efficiency, flexibility, and predictability, while ensuring that there are no adverse impacts on safety and giving due consideration to the environment. The ATM system must be resilient to service disruption and the resulting temporary loss of capacity.

- **Efficiency**: Addresses the operational and economic cost-effectiveness of gate-to-gate flight operations from a single-flight perspective. In all phases of flight, airspace users want to depart and arrive at the times they select and fly the trajectories they determine to be optimum.

- **Environment**: Contributes to the protection of the environment by considering noise, emissions, and other environmental issues in the implementation and operation of the aviation system.

- **Flexibility**: Ensures the ability of all airspace users to modify flight trajectories dynamically and adjust departure and arrival times, thereby permitting them to exploit operational opportunities as they occur.

- **Predictability**: The ability of airspace users and ATM service providers to provide consistent and dependable levels of performance. Predictability is essential to users as they develop and operate their schedules.

- **Safety**: Uniform safety standards and risk and safety management practices should be applied systematically to the air transpor-

tation system. In implementing elements of the system, safety needs to be assessed against appropriate criteria and according to appropriate and globally standardized safety management processes and practices.

NextGen Portfolios

As outlined in the NSIP, the FAA organizes operational improvements in 11 portfolios to group related initiatives for assessing, developing, and implementing new capabilities. Within a NextGen portfolio, each operational improvement is divided into capabilities that are deployed by increments as the technology or process becomes operational. The incremental capabilities in many cases immediately benefit the aviation community and help develop operational improvements. When the capabilities are in place, the operational improvement becomes a current operation. Primary and secondary benefits for each increment are also mapped.

Portfolio Descriptions

Milestones for these 11 portfolios are included in the section discussing detailed work plans.

Improved Surface Operations: Improved airport surveillance information, cockpit displays for increased situational awareness, and the deployment of a departure management decision support tool are some of the implementations within this portfolio. Improved Surface Operations safety features include surface moving-map displays in the cockpit, while surface movement data exchange and departure routing improvements enhance efficiency.

Improved Approaches and Low-Visibility Operations: Increased access and flexibility for approach operations will be accomplished through a combination of procedural changes, improved aircraft capabilities, and improved precision

approach guidance. Additionally, procedural changes allow for more efficient profiles.

Improved Multiple Runway Operations: This portfolio improves runway access through the use of enhanced technology, updated standards, safety analysis, air traffic tools, and operating procedures, which enables increased arrival and departure operations. Improving runway access will increase efficiency and capacity while reducing delays.

Performance Based Navigation (PBN): Improvements in aircraft navigation performance provide an opportunity to increase efficiency and flexibility. The PBN portfolio addresses ways to leverage emerging technologies, such as Area Navigation (RNAV) and Required Navigation Performance (RNP), to improve access and flexibility for point-to-point operations.

Time Based Flow Management (TBFM): System efficiency will be enhanced by leveraging Traffic Management Advisor (TMA) decision support tool capabilities. Further improvements will be made to enable controllers to accurately deliver aircraft to the terminal radar approach control facility (TRACON) while providing the opportunity for them to fly optimized descents and maintain spacing intervals, further improving capacity and flight efficiency.

Collaborative Air Traffic Management (CATM): NAS users and FAA traffic managers using advanced automation manage daily airspace and airport capacity issues (i.e., congestion, special activity airspace, and weather) by coordinating flight and flow decision-making. The overall philosophy driving the delivery of CATM services is to accommodate user preferences to the maximum extent possible (e.g., tailoring reroutes to specific flights).

Separation Management: Controllers are provided with tools and procedures to manage aircraft in a mixed environment of varying navigation equipment and wake performance capabilities. Aircraft separation assurance is the cornerstone of air traffic control operations. Separation management in the NAS can be accomplished procedurally and/or by using automation support.

On-Demand NAS Information: This portfolio ensures the consistency of airspace and aeronautical information across applications and locations, and are available to authorized subscribers and equipped aircraft. Users will request NAS information when planning flights through services that will allow them to collaborate with air navigation service providers, resulting in improved flow management and efficient use of resources.

Environment and Energy: The FAA's strategic environmental goal is to develop and operate a system that reduces aviation's environmental and energy impacts to a level that does not constrain growth and is a model of sustainability. Noise, air quality, climate, energy, and water quality are the most significant potential environmental constraints to increasing aviation capacity, efficiency, and flexibility. This portfolio describes the strategy to ensure compliance with the National Environmental Policy Act and the enabling technologies that support NextGen environmental goals.

System Safety Management: Develops and implements policies, processes, and analytical tools that the FAA and industry will use to ensure that changes introduced with NextGen enhance or do not degrade safety while delivering benefits.

NAS Infrastructure: This portfolio encompasses increments for systems that represent significant FAA investments or that have substantial cross-portfolio dependencies. As new services are established, the applicable increments that use these services or data from legacy sources will migrate to the new NAS infrastructure. The major focus areas of this portfolio include improved weather information and dissemination, data communications, and information management.

NextGen Priorities

The FAA and the aviation industry work together through the NextGen Advisory Committee to identify high-benefit, ready-to-implement capabilities developed in various NextGen portfolios to implement in the near term. (Current priorities are also covered in Appendix B and in the latest version of the NextGen Priorities Joint Implementation Plan.) The commitments fall into three categories: pre-implementation commitments, implementation commitments, and industry commitments (Figure A-2). Where applicable, these priorities are associated with each NextGen portfolio in timelines shown in the section discussing detailed work plans.

NEXTGEN PRIORITIES COMMITMENT CATEGORIES

Category	Description
Pre-Implementation	Agency pre-implementation activities, such as safety analyses, engineering studies, and investment analyses, for capabilities that the agency and aviation community are mutually interested in pursuing
Implementation	FAA commitments for operational implementations at specific locations, as applicable, that will be available for use upon completion
Industry	Industry's completion of activities required for successful implementation

Figure A-2

Detailed Work Plans

This section describes the detailed work plans for the 11 NextGen portfolios. The portfolios list operational improvements, current operations, and the corresponding capabilities of each; these portfolio components are associated with the years in which activities occur. The dates and timelines included in the tables are for planning purposes only and are based on information from the January 2020 NSIP. We have not accounted for how the COVID-19 public health emergency may have modified the milestones. All capability schedules are tentative until their supporting programs are officially baselined. A baseline is a reference point to assess the performance of a program over time.

Portfolios also are tagged to identify if the increment is associated with unmanned aircraft systems or space transportation, and show completion of all success criteria. Joint Implementation Plan commitments are aligned in the related portfolio along with tags that identify implementation category and completion status. See Figure A-3 for how to read the detailed work plans.

To preserve space in the tables, airport identifiers and acronyms associated with each operational improvement, current operation, segment, or commitment are decoded in Appendix C.

HOW TO READ DETAILED WORK PLANS

IMPROVED APPROACHES AND LOW-VISIBILITY OPERATIONS

NextGen Portfolio

Calendar Year

| 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |

OI: Operational Improvement
CO: Current Operation

Unique identifier for the OI/CO

OI: [107107] GBAS Precision Approaches (2012–2024)

[107107-21] GBAS Category II/III Standards and Non-Federal Approval (2019–2024)   C A E N P S

OI: [104211] Surface Traffic Management (2016–2028)

[104211-25] Establish Enhanced Data Exchange with Flight Operators (FOC) and Airport Operators (2016–2021)

Increment associated with an OI or CO
Color means phase

Increment also Joint Commitment

CO: [104115] Current Tactical Management of Flow in En Route for Arrivals and Departures (2016–2030)

[104115-21] Automation Support for Space Vehicle Operations (2021–2025)

| Planned |
| Concept Exploration and Maturation |
| Development |
| Initial Operationally Available |
| Completed |

Increment associated with

⚓ Unmanned Aircraft Systems
⭕ Space

Associated NextGen Benefit(s)

A Access and Equity
C Capacity
E Efficiency
N Environment
F Flexibility
P Predictability
S Safety

B Primary Benefit: The capability described in the increment, once achieved, will directly contribute to the realization of that benefit.

B Secondary Benefit: The capability will also improve the realization of the benefit, but not as significantly as the primary benefit.

NextGen Joint Commitment
Color means phase

	2019	2020	2021
Provide input and review the concept assessment to deconflict LGA/EWR/TEB when on LGA 13 ILS	■✓		
Joint Industry/FAA milestone to complete EFVS benefits studies to determine requirements for reaching Cat II/III equivalent operations in the NEC		◆✓	
Joint Industry/FAA milestone to complete studies to analyze the effects of mixed EFVS equipage aircraft operations in the NEC		◆✓	
Conduct GBAS evaluation/assessment at BOS		■	
PANYNJ will install non-Federal GBAS at LGA Q4 CY2020, and JFK			■

Calendar Year with Quarters

| Development |
| Completed |

Commitment Type and Status

● Pre-implementation
◆ Implementation
◆ Joint FAA/Industry
■ Industry
✓ Completed

Figure A-3

IMPROVED SURFACE OPERATIONS

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [102138] Enhanced Air Traffic Control Tower Services for Airport Operations at Non-Primary Airports (2017–2022)

[102138-01] Establish Air Traffic Control Tower Criteria for Airport Operations at Non-Primary Airports (2017–2022) — A C S

OI: [104117] Improved Management of Arrival/Surface/Departure Flow Operations (2015–2030)

P C, E — [104117-32] Improved Departure Operations using Mobile Applications (2023–2026)

CO: [104208] Enhanced Departure Flow Operations (2016–2019)

[104208-12] Revised Departure Clearance via Data Comm (2016–2019) — ✓ F S

OI: [104211] Surface Traffic Management (2016–2028)

[104211-21] TFDM Scheduler/Sequencer (2019–2021) — ◆ E N, P

[104211-22] Surface Metering Operations (2019–2021) — ◆ E F N

[104211-23] Improved Electronic Flight Data Exchange (2019–2020) — ◆ E

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
O Space   ◆ Implementation   ■ Industry   ✓ Completed

IMPROVED SURFACE OPERATIONS

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [104211] Surface Traffic Management (2016–2028)

[104211-24] Integrate Surveillance Data with Flight Data (Surface) (2025–2028) — E

[104211-25] Establish Enhanced Data Exchange with Flight Operators (FOC) and Airport Operators (2016–2021) ◆ E P

E S

[104211-26] Departure Clearances using Mobile Applications (2023–2026)

A E, P

[104211-27] Establish Enhanced Data Exchange through Mobile Applications (2023–2026)

	2019		2020		2021	
PANYNJ will exchange flight data with FAA/airlines at EWR, JFK and LGA through CDM partnership	■✓					
Participate and provide input during recurring SWIFT meetings	■✓	■✓	■	■	■	■
Review TFDM waterfall and denote airports that have a significant non-CDM flight operator presence		■✓				
NASA ATD-2 interim technology transfer from Phase 2: Fused IADS at CLT		●✓				
Benefits assessment for gate docking technologies to improve surface management		●✓				
PANYNJ will create new high-speed exit on JFK Runway 31R to reduce runway occupancy time		■✓				

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⋏ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
O Space   ◆ Implementation   ■ Industry   ✓ Completed

IMPROVED SURFACE OPERATIONS

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

	2019				2020				2021			
Southwest Airlines commits to provide improved aircraft intent data via surface data elements			■✓									
FedEx will provide improved aircraft intent data via surface data elements					■							
TFDM program will achieve key site IOC for Build 1 at PHX					◆							
TFDM program will complete operational testing for Build 1					●							
Collaborate with the FAA during all remaining CSIT visits: 2 visits; 2 visits; 3 visits; 3 visits					■		■		■			■
NASA ATD-2 final technology transfer from Phase 3: Terminal departure IADS at DFW/DAL						●						
Conduct assessment of DCA north end hold pads						■						
Conduct assessment of additional PHL 27L high-speed exits						■						
Conduct assessment of PHL 27R departure queue taxiway						■						
TFDM program will achieve ISD for Build 1 to allow additional TFDM system deployments into the NAS								◆				
Implement DSP enhancements								◆				
TFDM program will achieve IOC at 3 additional sites									◆			
TFDM program will achieve key site IOC for Build 2 at CLT										◆		
TFDM program will achieve ISD for Build 2 to allow additional deployments of the full TFDM capabilities into the NAS											◆	
TFDM program will achieve IOC at 5 additional sites												◆
Create additional BOS tower space for TFDM equipment to enable surface metering												■
Conduct assessment of PHL taxiway extension for end around operations												■

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

IMPROVED APPROACHES AND LOW-VISIBILITY OPERATIONS
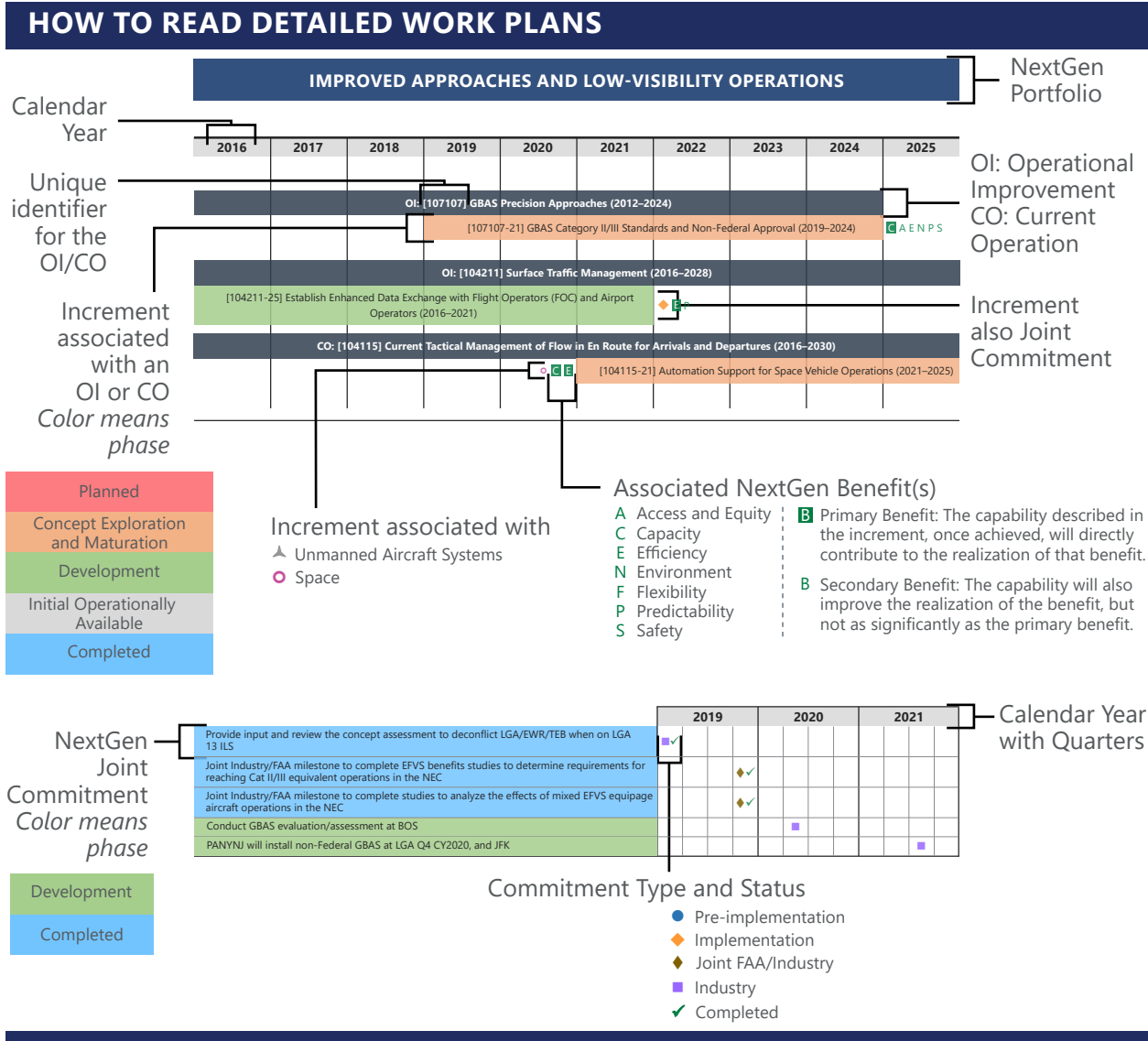
This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [107107] GBAS Precision Approaches (2012–2024)

[107107-21] GBAS Category II/III Standards and Non-Federal Approval (2019–2024) — C A E N P S

OI: [107117] Low-Visibility/Ceiling Approach and Landing Operations (2015–2021)

[107117-12] SVGS for Approach (2016–2021) — A C E

OI: [107202] Low-Visibility Surface Operations (2016–2022)

[107202-21] Low-Visibility Taxi Operations (2016–2020) — A C E

[107202-22] EFVS/Accurate Position Information for Taxi (2016–2020) — A C E

[107202-23] Protected Low-Visibility Taxi Route (2016–2020) — A C E

	2019	2020	2021
Provide input and review the concept assessment to deconflict LGA/EWR/TEB when on LGA 13 ILS	■ ✓		
Joint Industry/FAA milestone to complete EFVS benefits studies to determine requirements for reaching Cat II/III equivalent operations in the NEC		♦ ✓	
Joint Industry/FAA milestone to complete studies to analyze the effects of mixed EFVS equipage aircraft operations in the NEC		♦ ✓	
Conduct GBAS evaluation/assessment at BOS		■	
PANYNJ will install non-Federal GBAS at LGA Q4 CY2020 and JFK			■

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

| Planned | Concept Exploration & Maturation | Development | Initial Operationally Available | Completed |

▲ Unmanned Aircraft Systems   ● Pre-implementation   ♦ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

IMPROVED MULTIPLE RUNWAY OPERATIONS

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

CO: [102141] Improved Parallel Runway Operations for Arrivals (2012–2022)

[102141-22] Amend Standards for Simultaneous Independent Approaches - Dual with Offset (2016–2020) — ◆✓ A C E

[102141-24] Amend Standards for Simultaneous Independent Approaches - Triple (2016–2020) — ◆✓ C A, E

[102141-28] Amend Dependent Runway Separation Standards for Runways Spaced Greater Than 4,300 Feet (2016–2018) — ◆✓ C E

OI: [102159] CSPR Paired Departure Wake Mitigation (2021–2025)

C [102159-01] CSPR Paired Departure Wake Mitigation (2021–2025)

OI: [102161] Improved Parallel Runway Operations for Departures (2019–2023)

C E [102161-01] Dependent Stagger Departures for CSPO (2019–2023)

C E [102161-02] Further Reductions to Departure Divergence Requirements for CSPO (2019–2023)

C E [102161-03] Decreased Separation Requirements for Mixed Operations on CSPR (2019–2023)

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

IMPROVED MULTIPLE RUNWAY OPERATIONS

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

	2019				2020				2021			
CSPO collision risk safety study for HUR		●✓										
CSPO feasibility and initial safety analysis for departures			●✓									
Provide input and review feasibility and initial safety analysis for CSPO departure concepts				■								
Implement CRDA application for PHL 27R/35 for RNAV approaches				◆								
Analysis of use of RNAV (VNAV) approaches for 7110.308 at SFO					●							
Conduct CRDA feasibility analysis for EWR 22L/11 to lower minima					●							
Conduct CRDA feasibility analysis for EWR 4R/29 to lower minima					●							
Conduct analysis to evaluate the impact and benefit of applying 7110.308 at EWR					●							
Provide input and review CRDA feasibility analysis for EWR 22L/11 to lower minima					■							
Provide input and review of CRDA feasibility analysis for EWR 4R/29 to lower minima					■							
Provide input and review of FAA evaluation of the impact and benefit of applying 7110.308 at EWR					■							
CSPO feasibility and initial safety analysis for arrivals and departures							●					

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed	⊼ Unmanned Aircraft Systems	● Pre-implementation	◆ Joint FAA/Industry
					○ Space	◆ Implementation	■ Industry ✓ Completed

PERFORMANCE BASED NAVIGATION

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [107120] Resilient PBN Operations (2021–2025)

A E — [107120-01] Resilient En Route PBN Operations for DME-Equipped Aircraft (2021–2025)

OI: [108209] Increase Capacity and Efficiency Using RNAV and RNP (2010–2020)

[108209-20] Advanced and Efficient RNP (2013–2020) — ◆ E

[108209-22] Expansion of Metroplex PBN Procedures (2017–2020) — ◆ A E C

[108209-23] EoR Independent Duals and Triples with RF Procedures (2017–2020) — ◆ ✓ E

OI: [108215] Increase Capacity and Efficiency Using Streamlined PBN Services (2021–2030)

A E — [108215-01] PBN Airways (2021–2025)

E ◆ ✓ — [108215-02] EoR Independent Duals and Triples with TF Procedures (2021–2025)

E — [108215-03] More Optimal Metroplex PBN Procedures with TSAS (2021–2025)

C E ◆ — [108215-05] MARS (2023–2030)

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

| Planned | Concept Exploration & Maturation | Development | Initial Operationally Available | Completed |

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

PERFORMANCE BASED NAVIGATION

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

	2019			2020			2021		
Complete concept assessment to deconflict LGA/EWR/TEB when on LGA 13 ILS	● ✓								
Evaluate design alternatives to the GLDMN/NTHNS RNAV SIDs to address noise concerns		● ✓							
Conduct feasibility assessment of EoR simultaneous operations using JFK 13R RNAV RNP and 13L ILS approaches		● ✓							
Complete concept analysis for TEB RW19 RNAV SID for overnight operations		● ✓							
Conduct concept exploration of simultaneous operations on widely spaced approaches to different airports		● ✓							
Provide input to the evaluation of the alternatives to the GLDMN/NTHNS RNAV SIDs to address noise concerns		■ ✓							
Provide input and review feasibility assessment of EoR simultaneous operations using JFK 13R RNAV RNP and 13L ILS approaches		■ ✓							
Provide input and review concept analysis for TEB RW19 RNAV SID for overnight operations		■ ✓							
Identify and prioritize applications in the New York area for simultaneous operations on widely spaced approaches to different airports to expedite addressing deconfliction issues		■ ✓							
Participate in concept exploration of simultaneous operations on widely spaced approaches to different airports		■ ✓							
Determine viability and model ZDC airspace redesign alternatives			● ✓						
Evaluate LGA 31 RNAV approach design alternatives that approximate the LGA 31 EXPWY VIS approach and are usable for most operators			● ✓						
Complete concept assessment for EWR 22L/29 arrival operations			● ✓						
Provide input on ZDC airspace redesign alternatives to reduce traffic management restrictions			■ ✓						
Provide input to evaluation of designs for LGA 31 RNAV approach that approximates the LGA 31 EXPWY VIS approach and is usable for most operators			■ ✓						
Work with the FAA to mitigate climb gradient concerns to the GLDMN/NTHNS RNAV SIDs			■ ✓						
Provide input and review concept assessment for EWR 22L/29 arrival operations			■ ✓						
NBAA will support design of northbound and southbound escape routes			■ ✓						
Implement metroplex at LAS: 100 percent design complete; Implementation phase start; Implementation phase complete; Post-implementation phase complete			◆ ✓	◆	◆			◆	

	B Primary Benefit	B Secondary Benefit	A Access and Equity	C Capacity	E Efficiency	N Environment	F Flexibility	P Predictability	S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed	▲ Unmanned Aircraft Systems	● Pre-implementation	◆ Joint FAA/Industry
					○ Space	◆ Implementation	■ Industry	✓ Completed

PERFORMANCE BASED NAVIGATION

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

	2019			2020			2021		
PANYNJ with industry will conduct a review of existing PBN procedures, determine operator issues, identify needed modifications, and prioritize needed changes			■✓						
Implement metroplex at South-Central FL, SID and STAR: 100 percent design complete; Implementation phase start; Implementation phase complete			◆✓			◆		◆	
Implement metroplex at CLE/DTW: Post-implementation phase complete				◆					
Implement ZNY offshore PBN routes				◆					
Support design and implementation of ZNY offshore PBN routes				■					
Implement metroplex at DEN: Implementation phase start; Implementation phase complete; Post-implementation phase complete				◆	◆		◆		
Joint analysis with industry on potential barriers that inhibit the consistent use of EoR procedures at six NSG 1–4 airports in the NAS				◆					
Provide input, validate data, review findings, and confirm conclusions to post implementation analyses for implemented PBN procedures: CLE/DTW; DEN; LAS					■			■	■
Implement Eastern Seaboard high-altitude PBN routes (including SID/STAR connectivity) through ZBW, ZNY and ZDC airspace									◆
Continue to support ongoing design work and implementation of Eastern Seaboard high-altitude PBN routes (including SID/STAR connectivity) through ZBW, ZNY and ZDC airspace									■

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

TIME BASED FLOW MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [104117] Improved Management of Arrival/Surface/Departure Flow Operations (2015–2030)

E C, N — [104117-21] Expansion of the IDAC (2021–2025)

P E — [104117-22] Arrival Scheduling with Departure Data (2024–2028)

P E — [104117-23] Departure Scheduling with Arrival Data (2024–2028)

OI: [104120] Enhanced Time-Based Metering Operations in All Weather (2014–2025)

P E — [104120-21] Sustain Metering in Variable Operational Conditions (2024–2027)

E — [104120-22] Meet TBFM Constraints Using RTA Capability (2024–2027)

OI: [104123] Time-Based Metering Using RNAV and RNP Route Assignments (2014–2027)

E N — [104123-21] Lateral Maneuvering for Delay Absorption (Path Stretch) (2022–2026)

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed		

⋏ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✔ Completed

TIME BASED FLOW MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [104123] TBM Using RNAV and RNP Route Assignments (2014–2027)

E C, N — [104123-24] Rerouting During Metering Operations (2024–2027)

E N — [104123-25] OPDs to the Runway Enabled by RTA Capability (2023–2026)

OI: [104128] TBM in the Terminal Environment (2019–2028)

[104128-24] Initial TBM in the Terminal Environment (2019–2022) — E

E — [104128-25] Expanded TBM in the Terminal Environment (2024–2026)

	2019	2020	2021
Improve airborne metering to PHL	◆✓		
Complete review/update of adaptation for improving airborne metering to PHL	●✓		
Complete TBFM refresher training for metering to PHL	●✓		
Implement TBFM pre-departure scheduling at a selected airport (PIT to PHL)	◆✓		
Conduct an analysis to determine the sequence of remaining airports to receive en route metering	●✓		
Complete training of airspace user personnel to support TBFM pre-departure scheduling	■✓		

B Primary Benefit   **B** Secondary Benefit   **A** Access and Equity   **C** Capacity   **E** Efficiency   **N** Environment   **F** Flexibility   **P** Predictability   **S** Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

TIME BASED FLOW MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

	2019				2020				2021			
Improved departure management for flights destined to LGA					◆							
Implement select iTBO capabilities in NEC and DEN												◆
Improve Arrival Time Based Management to PHL												◆

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed	⚇ Unmanned Aircraft Systems ⭕ Space	● Pre-implementation ◆ Implementation	◆ Joint FAA/Industry ■ Industry ✔ Completed

COLLABORATIVE AIR TRAFFIC MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [101102] Provide Automated Flight Plan Constraint Evaluation with Feedback (2012– 2027)

E [101102-21] Constraint Evaluation Feedback (2021–2025)

E [101102-22] Additional Flight Plan Options and Preferences (2023–2027)

OI: [101103] Provide Flight Plan Evaluation and Feedback in all Phases of Flight (2018–2025)

[101103-21] Aircraft Access to Flight Planning Information (2018–2020) ✓ F E

CO: [104115] Current Tactical Management of Flow in En Route for Arrivals and Departures (2016–2030)

○ C E [104115-21] Automation Support for Space Vehicle Operations (2021–2025)

CO: [104208] Enhanced Departure Flow Operations (2016–2019)

[104208-11] Delivery of Pre-Departure Reroutes to Controllers (2016–2017) ✓ E F

OI: [105207] Full Collaborative Decision Making (2020–2030)

[105207-26] IDRP (2020–2022) P

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

▲ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

COLLABORATIVE AIR TRAFFIC MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [105208] TMI with Flight-Specific Trajectories (2012–2025)

[105208-21] Airborne Rerouting (2016–2017) ✓ E F

[105208-24] Aircraft Equipage Eligibility During TMIs (2023–2027) E

[105208-25] Advanced Flight-Specific Trajectories (2023–2027) C F E

CO: [105302] Initial Flight Day Evaluation (2011–2018)

[105302-27] User Input to Improve Departure Predictions (2016–2018) ✓ E P

OI: [105303] Advanced Flight Day Evaluation (2020–2028)

[105303-21] Improve Demand Predictions (2021–2023) E C

[105303-22] Probabilistic Constraint Prediction (2023–2027) E

[105303-23] Integrate TMI Modeling (2023–2027) E P

[105303-24] Enhanced Post Operations (2023–2027) E

B Primary Benefit	B Secondary Benefit	A Access and Equity	C Capacity	E Efficiency	N Environment	F Flexibility	P Predictability	S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems
○ Space
● Pre-implementation
◆ Implementation
◆ Joint FAA/Industry
■ Industry
✓ Completed

COLLABORATIVE AIR TRAFFIC MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [105303] Advanced Flight Day Evaluation (2020–2028)

E C	[105303-25] Airport Acceptance Rate Decision Support (2023–2027)
C E F	[105303-27] Improve SAA-Based Flow Predictions (2023–2027)

	2019				2020				2021			
Expand consistent usage of defined and existing capping and tunneling for departures/arrivals to/from the NEC	◆✓											
Conduct a feasibility study to create a process to reduce and/or eliminate passback MIT for departures from New York	●✓											
Conduct IDRP prototype re-familiarization session					●							
Conduct operational analysis to identify enhancements to improve data-driven TFM decision-making					●							
Provide input and review operational analysis to identify enhancements to improve data-driven TFM decision-making					■							
Implement PDRR/ABRR enhancements								◆				
Evaluate the use of multi-route TOSs to communicate departure and arrival trajectory preferences from/to PHL and New York area airports												■

B Primary Benefit　**B** Secondary Benefit　**A** Access and Equity　**C** Capacity　**E** Efficiency　**N** Environment　**F** Flexibility　**P** Predictability　**S** Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems　　● Pre-implementation　　◆ Joint FAA/Industry
○ Space　　◆ Implementation　　■ Industry　　✓ Completed

SEPARATION MANAGEMENT

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2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

CO: [102105] Current Oceanic Separation (2016–2030)

[102105-21] ASEPS for the Ocean (2020–2023) — C E, S

CO: [102108] Oceanic In-Trail Climb and Descent (2010–2016)

[102108-12] Enhanced Oceanic Climb/Descent Procedure via ADS-C Automation (2016) ✓ E

[102108-13] ADS-B Oceanic ITP and Automation (2011–2016) ✓ E

OI: [102117] Reduced Horizontal Separation Standards, En Route - 3 Miles (2020–2030)

S E [102117-22] Active Surveillance Collision Avoidance (2020–2025)

B Primary Benefit **B** Secondary Benefit **A** Access and Equity **C** Capacity **E** Efficiency **N** Environment **F** Flexibility **P** Predictability **S** Safety

Planned | Concept Exploration & Maturation | Development | Initial Operationally Available | Completed

△ Unmanned Aircraft Systems ○ Space ● Pre-implementation ◆ Implementation ◆ Joint FAA/Industry ■ Industry ✓ Completed

SEPARATION MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [102137] Automation Support for Separation Management (2014–2025)

[102137-29] More Efficient Merging of Terminal Arrival Flows (2019–2024)

OI: [102146] Improved Aircraft Trajectories (2024–2031)

E F C, N   [102146-23] Initial Air-Ground Synchronization of Aircraft Intent (2024–2027)

OI: [102154] Wake Re-Categorization (2014–2020)

[102154-21] Wake Re-Categorization Phase II - Static, Pair-wise Wake Separation Standards (2016–2018)   ◆ C E

OI: [102157] Improved Parallel Runway Operations with Airborne Applications (2020–2030)

S   [102157-31] Operation Specific Collision Avoidance (2020–2026)

C   [102157-32] MRS Reduction in the Terminal Environment (2021–2025)

OI: [102158] Automated Support for Initial Trajectory Negotiation (2019–2027)

C E, F, S   [102158-03] Enhanced En Route Data Comm Services (2024–2027)

B Primary Benefit   **B** Secondary Benefit   **A** Access and Equity   **C** Capacity   **E** Efficiency   **N** Environment   **F** Flexibility   **P** Predictability   **S** Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
O Space   ◆ Implementation   ■ Industry   ✔ Completed

SEPARATION MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

CO: [103201] Current Traffic Advisory (2016–2030)

⏚ S A [103201-01] UAS Detect and Avoid (2022–2026)

OI: [104102] Optimized Oceanic Trajectories via Interactive Planning (2020–2029)

S [104102-30] Enhanced Conflict Probe for ATOP Surveillance Airspace (2020–2025)

OI: [108214] UAS Airspace Access (2017–2022)

[108214-01] UAS Airspace Access when Operating within Visual Line of Sight (2017–2018)

⏚ S E, F, P

[108214-02] UAS Airspace Access when Operating Beyond Visual Line of Sight (2019–2022)

⏚ S E, F, P

	2019			2020			2021		
BOS and DFW CWT separation standards	◆✓								
Operator guidance material on wake turbulence encounter reporting		●✓							
Dynamic wake separation research			●✓						
ORD wake encounter and mitigation analysis			●✓						
Joint Industry/FAA milestone to assess opportunities to expand the use of CDTI-assisted operations beyond CAVS			◆✓						
CWT separation standards: 5 sites; 7 sites; 5 sites			◆✓			◆			◆
Reduced MRS feasibility study				●					
Wake turbulence encounter reporting				■					

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⏚ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
O Space   ◆ Implementation   ■ Industry   ✓ Completed

SEPARATION MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

	2019				2020				2021			
Provide input and review feasibility study of reduced MRS						■						
Conduct FIM and NEC-specific benefits study							●					
Joint Industry/FAA milestone to review the relevant information and recommend next steps of FIM							◆					
CWT benefits analysis								■				
Baseline enhanced Data Comm services for en route using the existing FANS 1/A message set											●■	

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
O Space   ◆ Implementation   ■ Industry   ✓ Completed

ON-DEMAND NAS INFORMATION

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [101203] UAS Flight Information (2017–2022)

[101203-01] Initial Notification and Authorization Planning for Part 101 and Part 107 Operators (2017–2018) ✓ S F

[101203-02] UAS Flight Information Management System (2019–2022) ⊿ S F

OI: [103211] Small UAS Advisory Services (2020–2025)

⊿ A S [103211-01] UAS Advisory Information (2020–2025)

⊿ A S [103211-02] Traffic Advisory Services for Small UAS (2022–2025)

OI: [103305] On-Demand NAS Information (2011–2020)

E S [103305-12] Improved Access to NAS Aeronautical, Status, and Constraint Information for Authorized NAS Users and Subscribers (2018–2020)

OI: [103306] Tailored Delivery of On-Demand NAS Information (2019–2025)

E [103306-01] Static Airspace Constraints (2022–2025)

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊿ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

ON-DEMAND NAS INFORMATION

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [108206] Flexible Airspace Management (2021–2030)

P C, E — [108206-34] Increased Flexibility in Inter-Facility Sector Transfer (2021–2025)

OI: [108212] Improved Management of SAA (2015–2025)

[108212-11] ANSP Real-Time Status for SAAs (2020–2023) E

[108212-21] Improved Access to SAA Information (2018–2022) E P

E [108212-24] Planned Airspace Constraints (2023–2025)

B Primary Benefit   **B** Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⅄ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✔ Completed

ENVIRONMENT AND ENERGY

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [701103] Integrated Environmental Modeling – Phase II (2016–2020)

[701103-01] Aviation Environmental Tools Suite (2016–2020) — N

OI: [701104] Integrated Environmental Modeling – Phase III (2021–2025)

N [701104-01] Aviation Environmental Tools Suite – Phase III (2021–2025)

CO: [702102] NextGen Environmental Engine and Aircraft Technologies – Phase I (2012–2017)

[702102-07] Ultra High-Bypass Ratio Geared Turbo Fan (2015–2017) ✓ N

OI: [702103] NextGen Environmental Engine and Aircraft Technologies – Phase II (2016–2020)

[702103-03] Explore and Demonstrate New Technologies Under CLEEN – Phase II (2016–2020) N

OI: [702104] NextGen Environmental Engine and Aircraft Technologies – Phase III (2021–2025)

N [702104-01] Explore and Demonstrate New Technologies Under CLEEN – Phase III (2021–2025)

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned | Concept Exploration & Maturation | Development | Initial Operationally Available | Completed

⊼ Unmanned Aircraft Systems   ○ Space   ● Pre-implementation   ◆ Implementation   ◆ Joint FAA/Industry   ■ Industry   ✓ Completed

ENVIRONMENT AND ENERGY

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [703103] Sustainable Alternative Jet Fuels – Phase II (2016–2020)

[703103-01] Other Advanced Drop-In Aviation Alternative Jet Fuels – Phase II (2016–2020) N

[703103-02] Generic Methodology for Alternative Jet Fuel Approval (2016–2020) N

OI: [703104] Sustainable Alternative Jet Fuels – Phase III (2021–2025)

N [703104-01] Support Qualification and Deployment of Drop-In Alternative Jet Fuels (2021–2025)

OI: [704103] Environmental Policies, Standards, and Measures – Phase II (2016–2020)

[704103-01] Environmental Performance and Targets – Phase II (2016–2020) ✓ N

[704103-03] EMS Data Management (2016–2020) ✓ N

[704103-04] Analysis to Support International Environmental Standard-Setting – Phase II (2016–2020) ✓ N

OI: [704104] Environmental Policies, Standards, and Measures – Phase III (2021–2025)

N [704104-01] Environmental Performance and Targets – Phase III (2021–2025)

N [704104-02] Analysis to Support International Environmental Standard-Setting – Phase III (2021–2025)

B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

SYSTEM SAFETY MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [601103] Safety Information Sharing and Emergent Trend Detection (2016–2020)

[601103-01] Additional ASIAS Participants (2016–2020) S

[601103-02] NextGen Enabled Data (2016–2020) S

[601103-03] Architecture Evolution and NextGen Support (2016–2020) S

[601103-04] Analytical Capabilities in Support of NextGen (2016–2020) S

[601103-05] Automated Vulnerability Discovery (2016–2020) S

[601103-06] Continued Studies and Results (2016–2020) S

[601103-07] Expanded Collaboration Environments (2016–2020) S

OI: [601104] Automated Safety Information Sharing and Analysis (2021–2025)

S [601104-01] Expanded Participation (2021–2025)

S [601104-02] Data Fusion (2021–2025)

S [601104-03] Expanded Analytical Capabilities to Include New Entrants (2021–2025)

S [601104-04] Vulnerability Discovery through Automated Trend Detection (2021–2025)

B Primary Benefit   **B** Secondary Benefit   **A** Access and Equity   **C** Capacity   **E** Efficiency   **N** Environment   **F** Flexibility   **P** Predictability   **S** Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems
O Space

● Pre-implementation
◆ Implementation

◆ Joint FAA/Industry
■ Industry
✔ Completed

SYSTEM SAFETY MANAGEMENT

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [601202] Integrated Safety Analysis and Modeling (2014–2025)

[601202-05] Integrated NAS-wide Automation System Modeling and Anomaly Detection (2016–2020) — S

S — [601202-06] Integrated Tools for Safety Risk Assessment Modeling (2021–2025)

OI: [601302] Increase International Cooperation for Aviation Safety (2019–2025)

S — [601302-01] EUROCONTROL-FAA Joint Analytical Platform Development and Deployment (2019–2025)

B Primary Benefit   **B** Secondary Benefit   **A** Access and Equity   **C** Capacity   **E** Efficiency   **N** Environment   **F** Flexibility   **P** Predictability   **S** Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⋏ Unmanned Aircraft Systems
○ Space

● Pre-implementation
◆ Implementation

◆ Joint FAA/Industry
■ Industry
✔ Completed

NAS INFRASTRUCTURE

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [102158] Automated Support for Initial Trajectory Negotiation (2019–2027)

[102158-01] Initial En Route Data Comm Services (2019–2021) ◆ **C** E, F, N, S

E C, F, N, S ◆ [102158-02] Full En Route Data Comm Services (2022–2025)

OI: [102163] Aircraft Collision Avoidance for Additional Aircraft Types (2023–2030)

⊼ **S** [102163-31] Collision Avoidance for UAS (2023–2028)

OI: [103119] Initial Integration of Weather Information into NAS Automation and Decision Making (2012–2022)

[103119-11] Enhanced NAS-Wide Access of 0-2 Hours Convective Weather on Traffic Forecast for NextGen Decision Making (2020–2022) **E** P, S

[103119-13] Enhanced In-Flight Icing Diagnosis and Forecast (2014–2022) **S** E

[103119-14] Enhanced Weather Radar Information for ATC Decision Making (2020–2022) **S** E

[103119-15] Extended Convective Weather on Traffic Forecast for NextGen Decision Making (2020–2022) **E** P, S

B Primary Benefit   **B** Secondary Benefit   **A** Access and Equity   **C** Capacity   **E** Efficiency   **N** Environment   **F** Flexibility   **P** Predictability   **S** Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed	⊼ Unmanned Aircraft Systems	● Pre-implementation	◆ Joint FAA/Industry
					○ Space	◆ Implementation	■ Industry ✔ Completed

NAS INFRASTRUCTURE

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [103119] Initial Integration of Weather Information into NAS Automation and Decision Making (2012–2022)

[103119-16] CWAM for Arrival/Departure Operations (2018–2022) — E P

[103119-17] 4-D Tailored Volumetric Retrievals of Aviation Weather Information (2018–2022) — E S

[103119-18] Enhanced Turbulence Forecast and Graphical Guidance (2018–2022) — E S

[103119-19] Enhanced Ceiling and Visibility Analysis (2012–2022) — E

[103119-21] Enhanced Convective Weather Using Satellite-Based Observation in Offshore Oceanic Airspace (2017–2024) — E P, S

OI: [103123] Full Integration of Weather Information Into NAS Automation and Decision Making (2021–2027)

E [103123-01] Aircraft-to-Severe Weather Notification (2021–2026)

E [103123-02] Net-Enabled Access to NextGen Common Weather Information Source – Enhanced (2021–2026)

E C [103123-03] Enhanced Icing Information (2021–2027)

E [103123-04] Expanded Turbulence Information (2021–2026)

E [103123-05] Generation of Enhanced NextGen Weather Information – Extended (2021–2026)

E [103123-06] Expanded Ceiling and Visibility Information (2021–2026)

Legend:
B Primary Benefit   B Secondary Benefit   A Access and Equity   C Capacity   E Efficiency   N Environment   F Flexibility   P Predictability   S Safety

Planned | Concept Exploration & Maturation | Development | Initial Operationally Available | Completed

▲ Unmanned Aircraft Systems   ○ Space   ● Pre-implementation   ◆ Implementation   ◆ Joint FAA/Industry   ■ Industry   ✔ Completed

APPENDIX A

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NAS INFRASTRUCTURE

This information is based on the January 2020 NSIP and does not account for the effects of the COVID-19 public health emergency.

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

OI: [103123] Full Integration of Weather Information Into NAS Automation and Decision Making (2021–2027)

E [103123-07] Enhanced Weather Products from Improved Satellite Observation Data (2023–2026)

E S [103123-08] Enhanced Automated Winter Weather Information (2017–2026)

E S [103123-09] Space Weather Information (2023–2026)

OI: [103306] Tailored Delivery of On-Demand NAS Information (2019–2025)

[103306-04] CSS-Wx (2019–2022) E S

	2019	2020	2021
Recommendation for target equipage rates for follow-on capabilities	◆✓		
Recommendation for regional jet equipage strategy	■✓		
Recommendation for target equipage rates for follow-on capabilities	■✓		
Deploy tower services to an additional seven towers	◆✓		
Loadability solution for runway SID/STARs	●✓		
Solution for full automation for the Confirm Assigned Route capability	●✓		
Airlines to equip 1,900 aircraft	■✓		
IOC for initial en route services at all CONUS ARTCCs			◆
Resolution of avionics/Pegasus 1 interoperability issue			■

B Primary Benefit   **B** Secondary Benefit   **A** Access and Equity   **C** Capacity   **E** Efficiency   **N** Environment   **F** Flexibility   **P** Predictability   **S** Safety

Planned	Concept Exploration & Maturation	Development	Initial Operationally Available	Completed

⊼ Unmanned Aircraft Systems   ● Pre-implementation   ◆ Joint FAA/Industry
○ Space   ◆ Implementation   ■ Industry   ✓ Completed

Trajectory Based Operations

Many of the current operations or planned operational improvements serve as building blocks for TBO, a principal goal for NextGen and the future NAS. TBO is an air traffic management method for strategically planning, managing, and optimizing flights throughout the operation by using time-based management, information exchange between air and ground systems, and the aircraft's ability to fly precise paths in time and space. TBO allows for more effective flight planning alongside smoother and more predictable operations throughout the NAS.

With TBO, controllers continue to assure separation based on where a flight is and improved predictions of where and when the flight is expected to be at key points. The aircraft's trajectory will be synchronized through automation by using improved and consistent information for better sequencing, which will reduce the need for less efficient rerouting. All flight trajectories competing for the same point in space at the same time will be sequenced to ensure appropriate spacing at those locations.

NextGen's path to TBO (Figure A-4) integrates capabilities that have already been deployed with new hardware and software to deliver on the operational vision. The capabilities are grouped into five themes:

- **Infrastructure**: Improvements to communications, navigation, surveillance, automation, and information exchange infrastructure that we implemented over the past decade. The FAA will continue to introduce new capabilities and enhance existing technologies in these areas to fully implement TBO. In 2019, we began deploying enhanced weather data and reporting products.

- **Integrated Arrivals**: Operational changes focused on the arrival phase of the operation, including navigation procedures and time-based management capabilities required

for TBO. For example, en route arrival metering using TBFM is already in place; terminal arrival metering began operation in 2020. Standard terminal arrival procedures with an optimized profile descent and the Established on RNP separation standard are already available in the NAS. We will deploy PBN enhancements for time-based spacing beginning in 2021.

- **Integrated Departures**: Operational changes at the airport and departure phase of the flight, including navigation procedures and time-based management capabilities necessary for TBO. Departures enabled by PBN and Data Communications (Data Comm) for departure clearances are available at many busy airports. Improvements for surface metering and electronic flight data will be deployed in the next two years to further improve collaborative decision-making between the FAA and aircraft operators.

- **Advanced Trajectory Management**: Operational changes focused on strategic and tactical management of aircraft trajectories. This includes operational changes planned for traffic management synchronization across the NAS. With improved strategic flight planning offered by the Traffic Flow Management System and System Wide Information Management in place, we will improve how we manage flights. In 2019, the FAA improved aircraft access to advanced flight planning information and began initial en route services for Data Comm.

- **Dynamic**: Operational changes envisioned for the final phase of TBO are in the earliest stages of planning and concept development. These changes are planned to begin in 2025 with dynamic wake separation and in 2026 with interval management, an Automatic
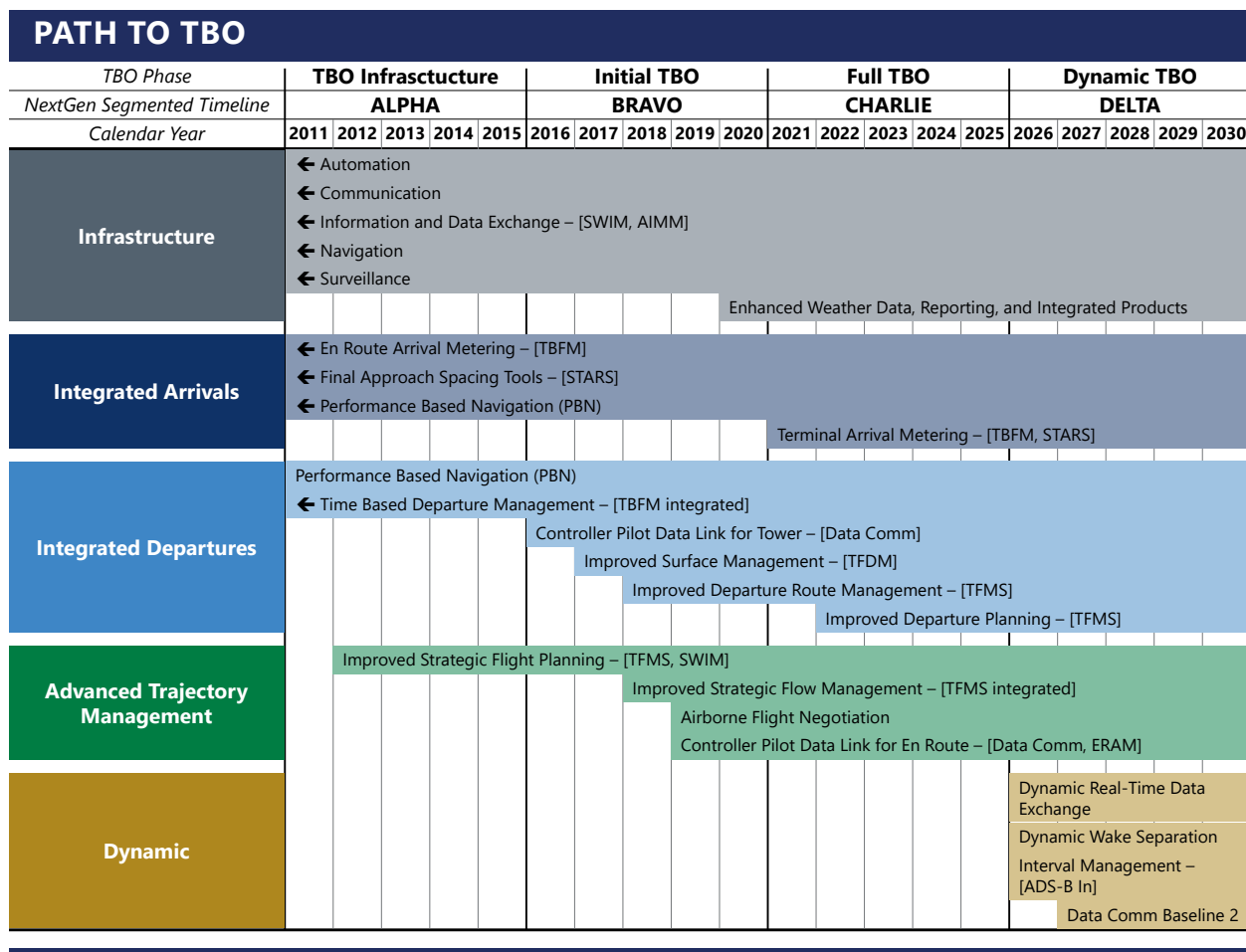
PATH TO TBO

TBO Phase	TBO Infrastructure	Initial TBO	Full TBO	Dynamic TBO
NextGen Segmented Timeline	ALPHA	BRAVO	CHARLIE	DELTA
Calendar Year	2011 2012 2013 2014 2015	2016 2017 2018 2019 2020	2021 2022 2023 2024 2025	2026 2027 2028 2029 2030

Infrastructure
- ← Automation
- ← Communication
- ← Information and Data Exchange – [SWIM, AIMM]
- ← Navigation
- ← Surveillance
- Enhanced Weather Data, Reporting, and Integrated Products (from ~2020)

Integrated Arrivals
- ← En Route Arrival Metering – [TBFM]
- ← Final Approach Spacing Tools – [STARS]
- ← Performance Based Navigation (PBN)
- Terminal Arrival Metering – [TBFM, STARS] (from ~2021)

Integrated Departures
- Performance Based Navigation (PBN) (from 2011)
- ← Time Based Departure Management – [TBFM integrated]
- Controller Pilot Data Link for Tower – [Data Comm] (from ~2016)
- Improved Surface Management – [TFDM] (from ~2017)
- Improved Departure Route Management – [TFMS] (from ~2018)
- Improved Departure Planning – [TFMS] (from ~2021)

Advanced Trajectory Management
- Improved Strategic Flight Planning – [TFMS, SWIM] (from ~2012)
- Improved Strategic Flow Management – [TFMS integrated] (from ~2018)
- Airborne Flight Negotiation (from ~2018)
- Controller Pilot Data Link for En Route – [Data Comm, ERAM] (from ~2018)

Dynamic
- Dynamic Real-Time Data Exchange (from ~2026)
- Dynamic Wake Separation (from ~2026)
- Interval Management – [ADS-B In] (from ~2026)
- Data Comm Baseline 2 (from ~2029)

Figure A-4: The integrated TBO capability will deliver the envisioned operational improvement. The capabilities in the shaded boxes represent when additional features will be available. Black left arrows to the left side of the chart indicate the initial capability was deployed before 2011.

Dependent Surveillance–Broadcast In application.

TBO implementation will evolve over time and be phased in at targeted locations beginning with the Northeast Corridor. This phased approach ensures that air traffic control facilities receive the right capabilities for their needs in the best sequence and at the correct time.

As the FAA extends TBO to new areas, we will choose from the available capabilities at the time of deployment. For example, if a location is slated for TBO in 2022, the FAA will assess whether integrated arrivals, integrated departures, and some initial advanced trajectory management capabilities, such as en route Data Comm, would provide an operational benefit. We will also determine which of those capabilities should be integrated into the initial TBO deployment for that area.

2020 and Beyond

Through NextGen, the FAA is implementing new technologies and air traffic control procedures that transform how we communicate, navigate, and track aircraft in our nation's skies. Publication of this document coincides with the end of Segment Bravo in the implementation timeline. The FAA anticipates that many of the capabilities organized in the detailed work plans will be operating in 2020 and beyond. ✈

APPENDIX B:

RETURN ON INVESTMENT REPORT

APPENDIX B:
Return on Investment Report

This appendix contains the text of the FAA's Return on Investment Report to Congress in response to Section 503 (Sec. 503) of H.R. 302, the FAA Reauthorization Act of 2018. Sec. 503 requires the preparation of a report on the return on investment (ROI) of each NextGen program. This report presents a summary of the cost-benefit analysis for each NextGen program and a summary of the most recent NextGen priority list that reflects the need for a balance between long-term and near-term user benefits.

Summary of Return on Investment of Major NextGen Programs

This report focuses on the following major acquisition programs within the NextGen Facilities and Equipment budget and primarily draws from the official business case analysis reports produced by each program:

- ADS-B (Automatic Dependent Surveillance – Broadcast), including Surveillance and Broadcast Services (SBS) Future Segments

- AIMM (Aeronautical Information Management Modernization) Segment 2 (S2)

- CSS-Wx (Common Support Services – Weather)

Program	Calculation Year	Net Present Value ($M)	Benefit/Cost Ratio	Payback Year
ADS-B	FY07	$ 552.0	1.1	2032
SBS Future Segments FY14-FY20	FY12	$ 901.2	1.2	2032
SBS Future Segments FY20-FY25	FY19	$ 4,797.0	2.64	2022
AIMM S2	FY14	$ 24.4	1.26	2027
CSS-Wx	FY14	$392.0	3.18	2020
Data Comm S1P1	FY12	$1,049.0	1.51	2033
Data Comm S1P2	FY15	$ 1,955.0	2.52	2028
ERAM EE2	FY18	$ -156.47	0.06	N/A
NWP	FY14	$ 918.0	5.88	2021
SWIM Segment 1	FY07	$ 271.8	1.7	2010
SWIM Segment 2A	FY12	$ 104.8	1.2	2016
SWIM Segment 2B	FY15	$ 51.0	1.3	2025
TBFM WP2	FY10	$ 101.38	2.36	2013
TBFM Enhancement 1	FY15	$ 291.0	2.84	2026
TFDM	FY16	$ 17.0	1.03	2047
TFMS/CATM WP2	FY08	$ 242.5	3.41	2015
TFMS/CATM WP3	FY09	$ 3.0	1.06	2022
TFMS E4	FY16	$ 246.0	8.41	2021

Table ES-1: Summary of ROI Data for Each NextGen Program.

- Data Comm (Data Communications) Segment 1 Phase 1 (S1P1) and Segment 1 Phase 2 (S1P2)

- ERAM (En Route Automation Modernization) System Enhancements and Tech Refresh, Enhancements 2 (EE2), and Sustainment 2

- NWP (NextGen Weather Processor)

- SWIM (System Wide Information Management) Segments 1, 2A, and 2B

- TBFM (Time Based Flow Management) Work Package 2 (WP2) and Enhancement 1

- TFDM (Terminal Flight Data Manager)

- Collaborative Air Traffic Management Technologies (CATMT) Work Package 2 (WP2), Work Package 3 (WP3), and TFMS (Traffic Flow Management System) Enhancement 4 (E4).

These comprise the capital programs that have been funded through the NextGen budget that have achieved successful Final Investment Decisions (and thus have established acquisition baselines) at the time of writing.

Table ES-1 summarizes the return on investment data of each program. This information is extracted from the official business case analysis reports (BCAR) produced by each program as part of their progression through the FAA Acquisition Management System (AMS). No attempt has been made to update these individual studies, which date from as early as 2007, to reflect changes to their underlying assumptions.

Summary of NextGen Priority List

The NextGen priority list is drawn from the latest FAA Joint Implementation Plan, which is informed by independent advice and recommendations from the NextGen Advisory Committee

(NAC). The current priorities consist of five focus areas:

- Multiple Runway Operations

- Performance Based Navigation

- Surface and Data Sharing

- Data Communications

- Northeast Corridor.

The FAA and industry have identified commitments within each of the focus areas to increase safety; reduce aviation's impact on the environment; enhance controller productivity; and increase predictability, airspace capacity, and efficiency.

1. Introduction

The Next Generation Air Transportation System (NextGen) is the Federal Aviation Administration (FAA)-led modernization of our nation's air transportation system. Its goal is to increase the safety, efficiency, capacity, predictability, and resiliency of American aviation. This overhaul brings together innovative technologies, capabilities, and procedures that improve how we fly from departure to arrival.

Airlines, pilots, and air traffic controllers gain better information and tools to help passengers and cargo arrive at their destinations more quickly, while aircraft consume less fuel and produce fewer emissions. This transformation is being achieved through an ongoing rollout of improvements which began in 2007. NextGen remains on target to have all major components in place by 2025.

This report responds to the requirements in Section 503 of H.R. 302, the FAA Reauthorization Act of 2018. Section 503 requires the FAA Administrator submit to Congress a NextGen "Return on Investment Report." The legislation defines return on investment as, "the cost asso-

APPENDIX B

ciated with technologies that are required by law or policy as compared to the financial benefits derived from such technologies by a government or a user of airspace." The report is to include, for each NextGen program:

- An estimate of the date the program will have a positive return on investment

- An explanation for any delay in the delivery of expected benefits from previously reported estimates on delivery of such benefits, in implementing or utilizing the program

- An estimate of the completion date

- An assessment of the long-term and near-term user benefits of the program for

  ○ (A) the Federal Government

  ○ (B) the users of the national airspace system, and

- A description of how the program directly contributes to a safer and more efficient air traffic control system.

Section 503 also stipulates that the Administrator shall develop, in coordination with the NextGen Advisory Committee (NAC), a prioritization of the NextGen programs.

a. Scope

NextGen is a wide-ranging endeavor, encompassing new technologies, procedures, and policies, for the FAA and aircraft operators. The FAA's NextGen budget includes Facilities and Equipment (i.e., capital investment); Operations; and Research, Engineering, and Development components. This report focuses on the following major acquisition programs within the NextGen Facilities and Equipment (F&E) budget:

- ADS-B (Automatic Dependent Surveillance – Broadcast), including Surveillance and Broadcast Services (SBS) Future Segments

- AIMM (Aeronautical Information Management Modernization) Segment 2 (S2)

- CSS-Wx (Common Support Services – Weather)

- Data Comm (Data Communications) Segment 1 Phase 1 (S1P1) and Segment 1 Phase 2 (S1P2)

- ERAM (En Route Automation Modernization) System Enhancements and Tech Refresh, Enhancements 2 (EE2), and Sustainment 2

- NWP (NextGen Weather Processor)

- SWIM (System Wide Information Management) Segments 1, 2A, and 2B

- TBFM (Time Based Flow Management) Work Package 2 (WP2) and Enhancement 1

- TFDM (Terminal Flight Data Manager)

- Collaborative Air Traffic Management Technologies (CATMT) Work Package 2 (WP2), Work Package 3 (WP3), and TFMS (Traffic Flow Management System) Enhancement 4 (E4).

These comprise the capital programs that have been funded through the NextGen budget that have achieved successful Final Investment Decisions (and thus have established acquisition baselines) at the time of writing.

b. Methodology

The most authoritative source of information regarding the return on investment of NextGen programs are the official business case analysis reports (BCAR) produced by each program as part of their progression through the FAA Acquisition Management System (AMS). Accordingly, this report primarily draws from the BCARs. Each BCAR is rigorously reviewed by the FAA's Office of Investment Planning and Analysis (IP&A). The data within the BCAR is considered authoritative

and forms the basis for acquisition decision milestones such as the Initial Investment Decision (IID) and Final Investment Decision (FID). Where available, for each program we present the investment's Net Present Value (NPV), Benefit/Cost (B/C) ratio, and the break-even year.

Per the FAA's Office of Aviation Policy and Plans Economic Analysis of Investment and Regulatory Decisions—Revised Guide,[1] NPV is defined as the discounted net present value of a series of outputs and resource inputs using the equation:

$$NPV = \sum_{t=0}^{k} \frac{(B-C)_t}{(1+r)^t} = \sum_{t=0}^{k} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{k} \frac{C_t}{(1+r)^t}$$

where

B_t and C_t are benefits and costs in year t,

r = the discount rate, and

k = the total number of periods in the evaluation period of the project.

Using the same terms, the B/C ratio is defined as the present value of benefits divided by costs using the equation:

$$B/C = \frac{\sum_{t=0}^{k} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{k} \frac{C_t}{(1+r)^t}}$$

For the NextGen priority list, this report draws from the latest FAA Joint Implementation Plan which is informed by advice from the NextGen Advisory Committee (NAC). The objective of the NAC, a chartered Federal Advisory Committee, is to provide independent advice and recommendations to the FAA and to respond to specific tasks received directly from the FAA. The NAC's advice, recommendations, and responses to FAA-assigned tasks relate to concepts, requirements, operational capabilities, the associated use of technology, and related considerations to operations that affect the future of the Air Traffic Management System. In addition, the NAC recommends consensus-driven standards for FAA consideration relating to Air Traffic Management System modernization, which the FAA may adopt. The joint plan focuses on delivering tangible implementation benefits across all NextGen focus areas and aligns the agency's and aviation community's priorities.

c. Organization

This report is organized into two major sections: the first documents the return on investment information for each major NextGen program, while the second covers the current NextGen priority list.

For each of the major NextGen programs, this report summarizes:

- the technological and procedural innovations that help the program contribute to a safer and more efficient air traffic control system

- how the program provides benefits to the Federal Government and to the users of the National Airspace System (NAS)

- the types of costs associated with implementing the program, and

- the economic analysis of the program, including an estimate of the date the program will achieve a positive return on investment.

The section on the NextGen priority list includes background on how the FAA collaborates with the aviation community through the NAC, the current NextGen priority list including the major focus areas, and how the priority list has been refined and evolved over time.

[1] https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/ECONOMIC.pdf

d. Assumptions and Limitations

This report draws heavily on information and data produced by various FAA entities, such as the individual program offices, dating back to 2007. While each program follows standard FAA guidelines, there may be slight inconsistencies in data sources and assumptions, which arise because the analyses that form the basis of these have been performed by different people at different points in time. No attempt has been made to update the studies cited here.

The references that form the basis for this report were all completed well before the onset of the global pandemic associated with the novel coronavirus. The impact of this pandemic on the aviation industry has been dramatic. For example, domestic commercial passenger operations have declined by almost 65 percent year-over-year, while international operations have declined even more. Such a dramatic decrease in air traffic operations will profoundly affect the cost-benefit calculus of NextGen programs. In particular, projected operator cost savings and safety benefits will be greatly reduced until traffic returns to pre-pandemic levels. FAA implementation costs for these programs may also increase slightly, as program schedules become stretched out.

2. Major NextGen Programs

ADS-B

a. Program Description

Automatic Dependent Surveillance – Broadcast (ADS-B)[2] is an advanced surveillance technology that enables equipped aircraft, or surface vehicles, to broadcast their identification, position, altitude, velocity, and other information. This concept utilizes a position source on the aircraft, which is more accurate than existing radar-based surveillance sources, for broadcasting positional information approximately once per second. This feature provides improved accuracy and more timely information updates than conventional surveillance. The superior positional accuracy, and the ability to provide additional aircraft-derived flight parameters, will result in increased safety and efficiency in the national airspace system (NAS). ADS-B is automatic because no external stimulus is required; it is dependent because it relies on on-board navigation sources and on-board broadcast transmission systems to provide surveillance information to other users. The aircraft or vehicle originating the broadcast may or may not have knowledge of which users (which could be aircraft or ground-based) are receiving its broadcast.

ADS-B technology additionally facilitates the implementation of Traffic Information Service-Broadcast (TIS-B), ADS-B Rebroadcast (ADS-R), and Flight Information Service-Broadcast (FIS-B) to support enhanced situational awareness and other applications. TIS-B service provides traffic information to equipped aircraft and surface vehicles based on the conventional radar returns received for transponder-equipped aircraft. ADS-R provides traffic information to equipped aircraft based on ADS-B transmissions from aircraft on independent datalinks. FIS-B provides weather and NAS Status information to equipped aircraft.

The introduction of Surveillance and Broadcast Services (SBS) into the NAS will improve the safety and efficiency of some well-established operations that are currently supported by radar and other existing surveillance sources and facilitate the introduction of new applications that promise to improve safety and increase capacity. The FAA will use the new surveillance capability to provide Air Traffic Control (ATC) services and more accurate data for Traffic Flow Management (TFM) services. Users will use the surveillance and broadcast services capability to support flight operations.

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[2] This summary is primarily based on Business Case Analysis Report for Surveillance and Broadcast Services Program – May 2012 and Business Case Analysis Report for Surveillance and Broadcast Systems – August 2007.

ADS-B Segments 1&2

The SBS program integrated the existing Capstone system into its baseline and has managed the nationwide expansion of surveillance and broadcast services.

On August 27, 2007 the SBS program, which is responsible for the implementation of ADS-B, TIS-B, and FIS-B, received its final Joint Resources Council (JRC) baseline decision for Segments 1 and 2.

In Segment 1, SBS was baselined to:

- Achieve Initial Operational Capability (IOC) at five key service delivery points

- Integrate ADS-B into four ATC automation systems

- Collect data for the certification of separation standards

- Achieve official operational status in 2010

- Publish a proposed ADS-B final rule that would mandate ADS-B equipage

- Develop an integrated Concept of Operations (CONOPS)

- Award the SBS Service Provider Contract

- Finalize a backup strategy

- Publish the ADS-B "Out" Notice of Proposed Rulemaking

- Maintain and expand the Alaska infrastructure

- Conduct modeling for separation standards development

- Conduct Joint Acceptance Inspection in the Gulf of Mexico

- Perform standards development for ADS-B applications

- Complete separation standards reports for key service delivery points

- Publish the Final ADS-B Rule in the Federal Register.

Segment 2 included:

- Proliferation of aircraft equipage

- Aircraft-to-aircraft application development

- NAS-wide deployment of SBS

- Integration of nine surface surveillance systems with SBS.

SBS Future Segments FY14-FY20

The continued investment in SBS future segments from FY14 to FY20 is to accomplish the following:

- Continue provision of baseline services and applications. The SBS program acquired the majority of the services described above through the award of a service provider contract. The on-going subscription fees associated with continuing the capability require sustained F&E funding.

- Expand coverage in the Gulf of Mexico. The SBS baseline surveillance service includes ADS-B coverage for the US portion of the Gulf of Mexico. Adding additional ADS-B radio stations in Mexico will provide coverage over all of the Gulf of Mexico air traffic routes extending from US airspace into Mexico, thereby allowing reduced separation on both sides of the border and enabling more efficient handoffs between US and Mexican airspace.

- Implement ADS-B In-Trail Procedure (ITP) Application. The FAA chartered the ADS-B In Aviation Rulemaking Committee (ARC) to provide a forum for the US aviation community to define a strategy for incorporating ADS-B In technologies into the NAS. In September of 2011, the ARC produced

a report detailing a prioritized set of applications. The most near-term ADS-B In application proposed was the In-Trail Procedure (ITP). The objective of this application is to enable more frequent approval of flight level requests between properly equipped aircraft using a reduced separation standard in Oceanic Airspace, thereby improving flight efficiency and safety.

SBS Future Segments FY20-FY25

On May 27, 2019 the JRC made a final investment decision for ADS-B Baseline Services Future Segments for FY20 to FY25. Implementation is intended to be accomplished in three groups:

- **Group 1:** Oversees and manages the contract to ensure continuity of service. Group 1 focus areas include:

  º Subscription Fees

  º Program Management

  º FID Planning for 2025 JRC

  º Service Contract Re-compete

  º Gulf Asset Relocation

  º ADS-B Minimum Operational Performance Standards (MOPS) Changes.

- **Group 2:** Implements system upgrades to preserve baseline services and meet new security requirements. Address obsolescence and field issues. Group 2 focus areas include:

  º Sustainment

  º ADS-B Resiliency Assessment.

- **Group 3:** Improves existing capabilities/ services to effectively manage the enforcement of the ADS-B Rule. Group 3 focus areas include:

  º Radar Removal

º SAPT Enhancements

º Performance Monitor Enhancements

º STARS Fusion Phase 3

º 1090 Spectrum Congestion Mitigation.

b.   Benefit Estimates

The SBS benefits were estimated relative to the existing ATC system, with established procedures currently in effect. Historical data were combined with traffic projections to describe the baseline from which benefits could be measured. This reference point was modified, prior to estimating benefits, to reflect any approved future improvements to the baseline that are scheduled during the analysis time period. System effectiveness measures (e.g., a reduction in either accident rates or typical delay times) were applied to the estimated baseline level in order to derive expected benefits. The system effectiveness, the percent of the population equipped, and the percent of infrastructure installed are key drivers in all the benefit estimates. These factors combine to represent the level of benefits that are expected in the future.

The benefits are primarily associated with FAA cost avoidance and enhancements to safety, capacity and efficiency. FAA cost avoidance comes from a divestiture of certain primary and secondary surveillance radars across the NAS, and a reduction in vendor subscription charges due to value added services.

The radar divestiture strategy has evolved over time. The 2007 estimate suggested that approximately 190 secondary surveillance radars (SSRs), or around half, would be removed, and that the others along with primary radars would provide the backup for ADS-B surveillance and fulfill the requirements of the Department of Homeland Security (DHS). The cost avoidance estimate also assumed that 49 Surface Movement Radars (SMRs) from ASDE-X and ASDE-3 sites would eventually be removed.

The 2012 estimate assumed 175 SSRs and 49 SMRs would be removed, and that all en route SSRs and 42 terminal SSRs would be retained for backup.

In 2018, a PMO analysis identified 122 radars that can be removed from the NAS due to redundant coverage:

- 7 Primary Surveillance Radar (PSR) removals

- 65 SSR removals

- 25 full-site radar removals (25 PSR + 25 SSR).

The full-site and primary site removals will be funded by SBS and the SSR removals will be funded by the Spectrum Efficient National Surveillance Radar (SENSR) program. Removal of SMRs will no longer be pursued.[3] It may be possible to remove additional radars if the SENSR program provides sufficient overlapping surveillance coverage.

The safety benefits include reductions in accidents (e.g., midair collisions, weather-related accidents, runway collisions, Controlled Flight Into Terrain incidents) and improved Search and Rescue and medical evacuation for areas where there is limited surveillance in the current environment. The safety enhancements are associated with air-to-air capabilities, TIS-B/FIS-B services, and expanded surveillance and IFR services, both en route and on the airport surface. The efficiency benefits include reductions in weather deviations, reduced cancellations resulting from increased access to some Alaskan villages during reduced weather conditions, additional controller automation, and additional aircraft-to-aircraft applications. The efficiency benefits translate to savings in both aircraft direct operating costs and passenger travel time.

The historical baselines for the safety benefits were based on a careful review of National Transportation Safety Board (NTSB) aviation accident reports. Appropriate database search methodol-

ogies were developed for each accident type for which reductions are expected. The set of accidents identified for each category were compared to ensure that specific incidents were not counted more than once towards the potential benefits. The total historical number of accidents for each accident type was tabulated by category of operation or accident composition and compared with traffic counts over the same time period to estimate accident rates. Existing mandates for certain aircraft classes (such as the Terrain Awareness Warning System) were accounted for prior to estimating the effectiveness of ADS-B capabilities.

The efficiency baseline is primarily defined in terms of flight hours, delay hours, and fuel burn. Flight and delay times were estimated for each user group and by location in order to reflect the baselines associated with each benefit element. Flight and schedule data from the Traffic Flow Management System (TFMS) were combined with weather observations from the National Centers for Environmental Information (NCEI) to generate baselines under differing operating conditions. The FAA Aviation System Performance Metrics (ASPM) database integrates this information and was accessed to generate the baseline metrics needed to accurately portray the potential efficiency benefits. Some of the benefits rely on future schedules produced by the FAA NextGen organization and results from a discrete simulation of the NAS called the System Wide Analysis Capability (SWAC). SWAC is currently used by the NextGen Systems Analysis and Modeling Office to model the combined impact of proposed future NextGen improvements.

c. Cost Estimates

The cost estimate addresses the acquisition, implementation, operations and maintenance costs for the Surveillance and Broadcast Services Program as well as the costs to the user community. The cost estimate is based on historical actuals, known prime contractor subscription

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[3] Automatic Dependent Surveillance – Broadcast (ADS-B) Baseline Services Future Segments (BSFS) Benefits Basis of Estimate, May 2019.

costs, and program office inputs. For budgetary purposes, the maximum potential cost for performance incentive fees is included, equating to an additional seven percent of the subscription costs.

The estimate is based on the continuation of baseline services to include Subscription Fees, Gulf Asset Relocation, Program Management, Service Contract Re-compete, JRC Planning, Sustainment, Radar Removal, ADS-B MOPS Changes, 1090 Spectrum Congestion, ADS-B Resiliency Assessment, Changes to SAPT, Changes to Performance Monitor, and Fusion Phase 3.

User costs are comprised of the procurement and installation of avionics equipment needed to comply with the airspace rule, which requires ADS-B Out by January 1st, 2020 as well as optional equipment to support FIS-B/TIS-B services and ADS-B In applications. Cost estimates were developed for all user groups (Air Transport, General Aviation and Air Taxi, DOD, and vehicles) based on assumed levels of adoption over time as well as unit cost inputs from avionics vendors and Original Equipment Manufacturers (OEMs).

The Air Carrier & Commuter as well as the General Aviation and Air Taxi cost estimates are comprised of updated inputs for both unit costs and equipage rates. Air Carrier & Commuter costs reflect recent inputs from the OEMs. Recent market data was compiled to refresh the estimate for the General Aviation and Air Taxi community. The DOD cost estimates were based on inputs from the DOD to the original 2007 business case. There are no DOD ADS-B In costs because the original inputs suggested they would not use ADS-B In services or applications. Many DOD aircraft have onboard radar that provide some of the capabilities of ADS-B In.

d. Return on Investment Estimate

Using the results of the benefits analysis and the completed cost estimate, programmatic metrics (i.e., B/C ratio and NPV) were calculated to determine the economic value of the SBS program. The estimates were also adjusted for risk.

Table 1 presents the risk-adjusted results for Segments 1 and 2 across the program lifecycle of FY07 to FY35 as documented in the SBS BCAR report dated August 27, 2007.

Net Present Value (FY07$M)	$552.0
B/C Ratio	1.1
Payback Year	2032

Table 1

e. Changes from Previous Estimates

As described in the Program Description section above, the ADS-B program has expanded beyond its initial baseline; accordingly, additional return on investment information has been produced and is reported in this section.

Table 2 presents the risk-adjusted results for SBS Future segments FY14-FY20 from the SBS BCAR report dated May 9, 2012.

Net Present Value (FY12$M)	$901.2
B/C Ratio	1.2
Payback Year	2032

Table 2

Table 3 presents the risk-adjusted results for SBS Future segments FY20-FY25 from ADS-B Baseline Services Future Segments (BSFS) Final Investment Decision (FY20-FY25 briefing, dated May 19, 2019.

Net Present Value (FY19$M)	$4,797
B/C Ratio	2.64
Payback Year	2022

Table 3

AIMM

a. Program Description

The Aeronautical Information Management Modernization (AIMM) Program[4] is designed to provide the Federal Aviation Administration (FAA) and aeronautical information (AI) stakeholders with digital aeronautical data that is authoritative, transformable and secured. To ensure full utilization by stakeholders, AI data needs to be fully integrated (fused) with other domain information including flight and flow, surveillance, and weather to provide a common operational picture of the NAS. The JRC made a Final Investment Decision (FID) for AIMM Segment 2 in August 2014. The program is now in the solution implementation phase. The AIMM Segment 2 (S2) Program meets these needs and is scheduled to be complete in July 2020.

AIMM S2 will deliver a software system developed on modular service-oriented architecture principles. FAA and NAS stakeholders will access integrated AI in multiple formats and customize delivery and visualization. AIMM S2 will support more intelligent use of the NAS through analytics, thereby improving operational efficiency. As a result of the capabilities developed by AIMM S2, an infrastructure will be established for the creation of an "information view" across the entire NAS. AIMM S2 is included in the NAS Enterprise Services Roadmap of the NAS Enterprise Architecture (EA).

AIMM S2 will modernize the ingestion, integration, management, maintenance, and distribution of AI by establishing the Aeronautical Common Services (ACS) and a OneStop-Shop (OSS) portal. AIMM S2 will become the single trusted access point of AI, for internal and external NAS consumers, moving the FAA from a simple product-centric environment to true AI management. AIMM S2 AI includes Notices to Airmen (NOTAMs), Special Activity Airspace (SAA) defini-

tions, SAA schedules, airport data, and other NAS infrastructure data. AIMM S2 will create a solid foundation for future AIMM segments, delivering greater access, integrity, and extensibility of AI systems to users across the NAS. The AIMM S2 design will leverage the System Wide Information Management (SWIM) investment by using the NAS Enterprise Messaging Service (NEMS) for data collection and AI distribution, thus providing a netcentric enterprise architecture.

AIMM S2 will modernize the NAS Resource (NASR) system by giving it access to the capabilities and services being developed in AIMM S2. This will provide for improved efficiency and operations at the National Flight Data Center and improve the management and integrity of key aeronautical data.

The AIMM S2 system will not retire or eliminate existing systems. Rather, it will enable more efficient and reliable connectivity with legacy systems while also providing a new avenue for the ingestion of aeronautical data, and access to operationally essential AI.

AIMM S2 will expand access to AI for the Department of Defense (DOD), air traffic control facilities, airlines, general aviation, and other authorized NAS users. The AI will be made available to all users in a standardized digital format using web-service-based, system-to-system interfaces and a single portal human-to-system interface. The AIMM S2 capabilities will improve and provide enhancement to the current processes for consuming AI. Each of the capabilities provided by the AIMM S2 program are designed to permit FAA and NAS stakeholders to consume integrated AI in multiple formats with customized delivery and visualization.

b. Benefit Estimates

The AIMM S2 Program has a portfolio of benefits that are based on the ACS capabilities, and various operational efficiencies derived from upgrading

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[4]This summary is primarily based on Final Business Case for Aeronautical Information Management Segment (AIMM S2), August 2014.

or consolidating current operations within the AIMM Program. The AIMM S2 ACS provides the following capabilities:

- **Aeronautical Information Data Analytics (AIDA):** A capability enabled by integration of aeronautical data permitting the ability to perform analytics

- **Aeronautical Information Query and Subscription Service (AIQS):** The ability for consumers to pull or receive pushed (on demand, and/or at requested intervals) aeronautical data

- **One-Stop-Shop (OSS) Capability:** A single web portal designed to bring AI together from diverse sources in a uniform way

- **Spatial Information Mapping (SIM):** Ability to display digitalized data in a geo-referenced map view, providing integration and layering of information within a spatial context

- **Aeronautical Information Integration (AII):** Translation of information from disparate sources into a single consistent format, permitting integration and flexibility of consumption.

The AIMM S2 benefits portfolio consists of:

- **Temporary Flight Restriction (TFR) Violation Reduction:** TFR notices are currently distributed en masse through disparate dissemination, resulting in occasional input errors and commonly delayed dissemination of data. AIMM S2 Aeronautical Information Subscription Service (AISS) will provide the ability for consumers to pull, or have pushed (at requested intervals), specific TFRs (based on the consumer's need), providing timely updates of critical data in a consumable format.

- **EnRoute Violation Reduction:** With the AISS, AI consumers will receive easier to

read information directly into smart systems that map the information, and assist pilots with identifying NOTAMs that affect their particular flight.

- **Aeronautical Information Management (AIM) Systems Help Desk:** AIM Systems Help Desk Benefit consists of the consolidation of the AIM Legacy Help Desks (NAS Aeronautical Information Management Enterprise Systems II Help Desk) with the AIMM Segment 2 Help Desk. The consolidation of the AIM legacy Help Desks with the AIMM Segment 2 Help Desk will result in overall help desk efficiencies.

- **Infrastructure Enablement:** AIMM S2 benefit provided to all future AIM Segments to leverage key components of the AIMM S2 infrastructure components, reducing the costs of future AIM Segments. In addition, other programs (programs in development over the next ten years) will be able to leverage the AIMM S2 infrastructure.

- **Airport Violation Reduction:** AIMM S2 will permit consumers of AI (using the ACS) to produce geospatial displays of airport schematics.

- **Special Activity Airspace (SAA) Flight Path Savings:** The SAA schedules will be made available to NAS users through ACS (via static schedules). The flight path savings will include reduced flight time, flight distance, and fuel usage.

- **Better Management of SAA:** AIMM S2 Aeronautical Information Data Analytics (AIDA) will enable stakeholders to analyze historical SAA operations. As a result, continuous process improvement opportunities will be identified and realized based on the analysis of SAA usage data.

- **Aeronautical Information Safety Enhancements Benefit:** AIMM S2 will improve the ability of consumers accessing,

viewing, and integrating relevant AI. This will reduce the number of Near Midair Collisions (NMACs) and accidents.

- **ACS Subsumption of the NASR:** AIMM S2 will modernize the NASR system by giving it access to the capabilities and services being developed in AIMM S2. The ACS will provide the consumer with a single source of information from the Authoritative Source, to include SAA definitions from NASR, and procedures data from NAVLean. This will provide for improved efficiency and operations at the National Flight Data Center and improve the management and integrity of key aeronautical data. The AIMM S2 system will not preempt nor disable any existing legacy systems. It will enable more efficient and reliable connectivity with those legacy systems while also providing a new avenue for the ingestion of aeronautical data, and access to operationally essential Al.

c. Cost Estimates

The AIMM S2 Lifecycle Cost Estimate (LCCE) for FID was developed following the approach summarized below. The LCCE relies on the proposal pricing provided by the vendor (Northrop Grumman), which submitted a technical solution that combined a mix of COTS/Freeware and custom software to meet the AIMM S2 software release requirements. The program assumed a life-cycle of FY 2014-2035.

The AIMM S2 Life Cycle Cost Estimate was developed using inputs from four primary sources:

Risk-adjusted summary data from contractor: Contractor costs by Contract Line Item (CLIN) were mapped to the FAA WBS using information from the Contract Work Breakdown Structure (CWBS). Contractor phasing of cost was used to ensure alignment with the CWBS. Contractor pricing was risk adjusted using inputs from the cost evaluation team, PMO subject matter experts (SMEs), and both the AIMM S2

Program Team and Investment Planning & Analysis' (IP&A) experience from previous programs.

Program Management Office staffing study: A detailed study to assess the FAA and support contractor staffing necessary to provide oversight and evaluation during Solution Implementation and In-Service management was conducted by the Investment Analysis support staff. Functional groupings with specific skill sets were defined following the groupings from the Acquisition Workforce Study (Acquisition Workforce Staffing Analysis and Proposed Acquisition Workforce Staffing Model – 2008). A detailed list of activities to be performed by the staff was derived from the Contract Data Requirements Lists (CDRLs) and program reviews required per the Statement of Work (SOW). Hours of effort by skill set (both government and support contractor) were assessed by a team of SMEs with extensive experience supporting acquisition/delivery of numerous similar programs. Hours were converted to average annual FTEs and the appropriate government or contractor labor rate applied. Staffing was assigned the appropriate WBS based on the activity being performed.

Cost estimates for Telco and SWIM: The AIMM S2 Engineering Team worked with Telco and SWIM representatives to determine if the requirements developed for the IID were still relevant. Changes were made to reflect the final selection of the operating locations: Atlanta Air Route Traffic Control Center (ARTCC) for the primary and Salt Lake City ARTCC for the backup. Additionally, it was determined that AIMM S2 would not have to acquire a new NAS Enterprise Messaging Service (NEMS) node. The Communications, Information, and Network Programs (CINP) office provided costs for FY14-FY24. The estimate was extended through FY35 by extending the FY24 value. The expectation is that costs will remain constant or decline; AIMM S2 uses the more conservative value.

FAA Cloud Services: FAA Cloud Services (FCS) costs were provided by the FCS Program Manage-

ment Office using their Independent Government Cost Estimate (IGCE) as the source of costs. Capacity requirements were taken from the AIMM S2 IID hardware profile and include growth through FY35. Requirements for reliability and back-up (failover and remote back-up) were provided by the AIMM S2 engineering team. The FCS cost estimate covers the period FY19-FY24. FY24 costs were reduced by 20 percent beginning in FY25 and extended through FY35 based on the recommendation of the FCS staff.

General: Contractor labor rates are used to assess the labor hours. Rates from other CLINS were used to derive rates for Fixed Price CLINs. Government rates follow the guidance in Economic Information for Investment Analysis (EIIA) (April 2013). PMO support contractor rates are based on actuals from other FAA programs.

Inflation rates are from Economic Information for Investment Analysis (EIIA) (May 2014).

d. Return on Investment Estimate

The AIMM S2 Program Management Office conducted an economic analysis on the time-phased, economically adjusted costs and benefits. The economic analysis compared discounted risk-adjusted costs and discounted risk-adjusted benefits to determine the investment's benefit/cost (BC) ratio to summarize the overall value for money for the AIMM S2 Program. The economic analysis followed the guidelines of OMB Circular A–94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs (Revised) (October 29, 1992), as well as the standards defined by the Office of Investment Planning and Analysis (IP&A).

The economic analyses present the value of cost and benefits over the life of the program. Per FAA Office of Investment Planning and Analysis guidance, the costs reflect an 80th percentile confidence level, indicating that there is an 80 percent chance that actual costs will be below the esti-

mated costs. The benefits reflect the 20th percentile confidence level, indicating that there is an 80 percent chance that actual benefits will be greater than the estimated benefits.

The NPV indicates an investment's net value in today's dollars. The investment time period is FY2014 - FY2035. The first year with a positive cumulative discounted cash flow is 2027.

Table 4 summarizes the AIMM S2 economic analysis results.

Net Present Value (FY14$M)	$24.4
B/C Ratio	1.26
Payback Year	2027

Table 4

e. Changes from Previous Estimates

FAA Security review of AIMM S2 Release 2 identified security threats and resulted in a change to the AIMM S2 architecture. The AIMM S2 program has experienced performance issues with the prime vendor in the development of the third release resulting in delays to testing and development. Additionally, the 35-day break in non-essential operations resulted in the loss of the prime vendor's primary development and test personnel adding an additional 7 months to the schedule completion.

CSS-Wx

a. Program Description

Two weather programs were established to accomplish NextGen goals: Common Support Services – Weather (CSS-Wx)[5], formerly known as NextGen Network Enabled Weather (NNEW); and Weather Forecast Improvements-NextGen Weather Processor (NWP). The CSS-Wx Program covers the improvements needed to enable universal access to weather information specific to user needs,

[5]This summary is primarily based on Final Business Case for Common Support Services – Weather, Version 1.2, September 2014.

while the NWP Program covers the improvements in weather information quality.

The CSS-Wx System will be the single publisher of aviation weather information via System Wide Information Management (SWIM) to all FAA users. It will publish improved weather products from the NWP and the National Oceanic and Atmospheric Administration (NOAA) using the Open Geospatial Consortium (OGC) standards and extensions, as well as other weather sources. The CSS-Wx System will provide filtering and extraction of weather information by user-specified criteria, as well as mapping/projection, formatting, unit conversion, and product quantization. It will provide storage, archiving and retrieval of weather products. It will support FAA end user systems such as Traffic Flow Management System (TFMS), Time Based Flow Management (TBFM), and En Route Automation Modernization (ERAM).

The CSS-Wx System will have the following high level capabilities:

- Filter weather information geospatially and temporally to provide only the specific data requested by a user (e.g., along a flight path);

- Provide weather information via Web Coverage Service (WCS), Web Feature Service (WFS), and Web Map Service (WMS);

- Perform weather data management;

- Standardize weather information in common formats identified by the OGC;

- Store, archive, and retrieve weather information; and

- Manage discovery of information in real time.

The CSS-Wx System will publish improved weather products provided by NWP, NOAA, and other weather sources to FAA and National Airspace System (NAS) users for input into collab-

orative decision making. Consumers of CSS-Wx information will include air traffic, commercial aviation, general aviation, and the flying public. CSS-Wx will make weather information available for NextGen's enhanced decision support tools. Other consumers will include the Department of Defense, the Department of Homeland Security, and NOAA.

b. Benefit Estimates

The CSS-Wx System will provide network-enabled weather information services that will improve weather access capabilities and facilitate integration of weather information into Air Traffic Management (ATM) Decision-Support Tool (DST). It will define, develop, and provide capabilities for universal access to weather information from multiple government and industry sources in a SWIM-compatible network. It will define common standards for weather services and weather data formats and provide the capability for the extraction of weather information by user-specified criteria.

These enhanced capabilities will produce more efficient management of weather information through:

- Discovery, caching, advanced filtering, and compression;

- Reducing development costs for tools requiring weather data through the development of global and open standards;

- Improving safety by reducing the number of encounters with weather hazards through greater situational awareness; and

- Aiding in reducing weather impact in the NAS.

The benefits analysis focused on the following benefit categories:

- Reduced future infrastructure costs to support forecast data bandwidth needs;

- Reduced costs to develop future custom weather interfaces;

- Improved operational ATM decision-making from enhanced access to weather products;

- Increased weather access leading to reduced accidents; and

- Legacy system cost avoidance.

The CSS-Wx Program's Final Investment benefits analysis utilized a separate approach to estimate each benefit area. There are several benefits categorized into three main elements: cost avoidance, flight efficiency, and safety. The cost avoidance benefits are monetized based on the estimated future costs to the FAA that can be avoided if the CSS-Wx System is implemented. The flight efficiency benefits are quantified in terms of fuel savings and/or delays (airborne, ground, gate) and monetized using values for fuel cost, Aircraft Direct Operating Cost (ADOC), and Passenger Value of Time (PVT). The safety benefits are quantified in terms of projected accidents and monetized using values for avoided fatalities, injuries, and aircraft damage. All benefit metrics were risk-adjusted in coordination with the Office of Investment Planning and Analysis (IP&A) to account for a wide range of uncertainties in data, approach, and models used.

c. Cost Estimates

The CSS-Wx life-cycle costs were estimated starting in year FY 2014 and ending in FY 2040. The FAA standard WBS, version 5.1, was used to model the costs. Each WBS element within the cost estimates was estimated in Base-Year 2014 dollars, time-phased, and inflated using the latest Office of Management & Budget (OMB) inflation indices to calculate the Then-Year point estimate. Risk analysis was then performed to calculate the High-Confidence Life-Cycle Cost (HCLCC) estimate for the Legacy Case and the new system.

A variety of estimating methodologies were used to derive point estimates for the system. The following paragraphs summarize the various techniques and data sources used to estimate the cost elements and calculate the high-confidence life cycle estimate.

The CSS-Wx system consists of a Facilities and Equipment (F&E) and an Operations and Maintenance (O&M) component. These costs include the costs of materials and Contractor/ Federal labor required to develop, test, and support the CSS-Wx system. The F&E component breaks down FAA labor as its own cost element, with the rest consisting of contractor labor and materials costs. The support contractor labor rate was based on the analogous FAA Program Office labor costs. Federal salaries were based on the government service schedule for estimating purposes and adjusted by the standard benefits factor. Risk analysis was performed to calculate the High-Confidence Life-Cycle Cost estimate for the two cases.

Cost inputs for non-prime contractor costs were provided by other organizations within the FAA. Level of effort inputs for Testing and Second Level Engineering activities were provided by persons within the appropriate departments within the FAA's Technical Center. Initial and recurring telecommunication costs were provided by the Future Telecommunications Infrastructure (FTI) program. Implementation costs for the system were based on input from Engineering Services (ES) and implementation Subject Matter Experts (SMEs). Logistics support costs (Federal and Support Contractor) were provided by Logistic subject matter experts.

In regard to the maintenance of the system, it is important to note that a contractor will provide software/hardware maintenance support not only through full deployment of the system, but also for the remainder of the lifecycle. The FAA's Second Level Organization role is that of oversight and support in regard to software maintenance. The FAA's TechOps will oversee the maintenance of the associated hardware

The CSS-Wx Prime Contractor costs for the solution were based on the successful offering of the CSS-Wx competitive procurement. These costs were provided by the vendor in twenty independent Contract Line Item Numbers (CLINs). These costs were then mapped into the appropriate CSS-Wx WBS elements for F&E and Operations and Support (O&S) costs. Prime Contractor activities will include Hardware Procurement, Software Development, Testing, Implementation, and In-Service maintenance (Corrective Maintenance, Logistics and 2nd Level Engineering).

The costs associated with the winning vendor's bids were much lower than the IGCE. The reason for this difference is that the IGCE assumed the vendor would have a far greater amount of software development and testing to perform. However, the selected proposal is leveraging a significant amount of previous work and a large amount of commercial-off-the-shelf items.

d. Return on Investment Estimate

Using the results of the benefits analysis and the completed cost estimate, programmatic metrics were calculated to determine the financial returns for the CSS-Wx System investment. The business case lifecycle is from 2014 to 2040.

The economic analysis compares the incremental cost to the incremental benefit. The incremental cost includes the development, operation, and support of the CSS-Wx System. The incremental benefit includes the legacy cost avoidance as well as the other quantified benefit categories.

The cost and benefit values represent a "high confidence" estimate from an underlying distribution of possible cost and benefit outcomes. In order to obtain similarly "high-confidence" economic analysis metrics, the full distributions of costs and benefits were statistically combined using a Monte Carlo simulation. These statistically combined results are presented in Table 5 below. The statistical combination of the cost and

benefit distributions results in a different NPV and benefit-cost (B/C) ratio than would result from simply subtracting the "high-confidence" risk-adjusted present value costs from the risk-adjusted present value benefits or from taking the ratio of the two values.

Net Present Value (FY14$M)	$392
B/C Ratio	3.18
Payback Year	2020

Table 5

e. Changes from Previous Estimates

The CSS-Wx Program is undergoing a re-plan due to a delay in the implementation associated with factors which include not completing software development. As part of the re-plan, the program is determining cost and schedule impacts.

Data Comm

a. Program Description

Data Comm[6] provides data communications services between pilots and air traffic controllers. Data Comm provides a direct link between ground automation and flight deck avionics for safety-of-flight ATC clearances, instructions, traffic flow management, flight crew requests and reports. Data Comm is critical to the success of NextGen operations, enabling efficiencies that are not possible using the current voice-based system.

These improvements to the NAS are delivered by Data Comm in two segments. Segment 1 delivers the initial set of data communications services integrated with automation support tools, which provide NAS benefits and lay the foundation for a data-driven NAS. Segment 1 is divided into two phases: Segment 1 Phase 1 (S1P1) implements departure clearance services in the air traffic control tower (baselined in May 2012), and Segment 1 Phase 2 (S1P2) addresses the En

[6]This summary is primarily based on Business Case Analysis Report for Data Communications Segment 1 Services and Final Business Case for Data Communications En Route Services (Segment 1, Phase 2)

Route deployment of Data Comm. S1P2 includes En Route Initial Services (baselined October 2014) and En Route Full Services (baselined in August 2016).

The Data Comm program office achieved a positive initial investment decision (IID) in July 2008 which allowed final investment activities to begin, and the program office received an authorization to proceed with development of some key portions of Segment 1 services in November 2010. Data Comm is being deployed through a phased deployment approach that began with providing the Revised Departure Clearance service at 55 airports.

This phase was deployed in 2015-2016, 29 months ahead of schedule. The JRC approved deployment to an additional seven airports in February 2017 using program underrun funds. The deployment to these seven additional airports was completed in 2017-2018, 13 months ahead of the original baseline schedule for the 55 airports.

S1P1 required software enhancements to the existing Tower Data Link Services (TDLS) and En Route Automation Modernization (ERAM) platforms, as well as development of the Data Comm network infrastructure. The benefits of Tower Data Comm Services to the user and the flying public include a reduction in gate and taxi departure times, communication times between pilot and controllers, readback/hearback errors, and environmental emissions. The reduced communications time is reducing overall delays in the NAS and is allowing for more efficient use of available capacity. In addition, Data Comm Tower Services are supporting a more rapid recovery from adverse weather events, which are reducing delays and enhancing overall predictability in the NAS.

S1P2 En Route Initial Services focuses on delivering additional services in the en route domain. S1P2 En Route Initial Services is scheduled to deploy 2019-2021. S1P2 En Route Full Services will implement additional capabilities in the en route domain, such as holding instructions and advisory messages, and is scheduled for deployment in 2022-2023.

The major elements of the S1P2 implementation are:

- ERAM enhancements to establish Controller-Pilot Data Link Communications (CPDLC) capability in the En Route domain

- TDLS software enhancements to provide additional services to tower controllers

- Data Comm Network Service (DCNS) expanded coverage and capacity

- FAA Telecommunications Infrastructure (FTI)

- Future Air Navigation System (FANS) 1/A avionics.

S1P2 En Route Initial Services achieved a successful Final Investment Decision (FID) in October 2014 and is currently in implementation. S1P2 En Route Full Services will leverage the existing infrastructure and equipage to deliver additional services in the En Route domain. S1P2 En Route Full Services achieved a successful FID in August 2016, and is scheduled to be deployed in 2022-2023.

Segment 2 will further build upon the Departure Clearance and En Route services by enabling the transfer of complex clearances and more advanced NextGen operations that are not possible using voice communications, such as four-dimensional trajectories, optimized profile descents, and advanced flight interval management.

Data Communications services require operators to have applicable avionics installed and enabled on their aircraft. The S1P1 Tower Services and the S1P2 Initial and Full En Route services will all utilize the currently available FANS 1/A standard via Very High Frequency (VHF) Data Link – Mode 2 (VDL-2). Data Communications will support Baseline 2 avionics in Segment 2.

b. Benefit Estimates

Data Comm transforms communication between the ground and the cockpit, providing services which enhance the efficiency of the NAS by enhancing airspace throughput and shortening flight times. The program enables controllers to send text-based air traffic messages, and enables flight crews to acknowledge and accept those messages with the push of a button, resulting in:

- Improved controller and flight crew efficiency as a result of automated information exchange

- Improved rerouting capabilities

- Delivery of more efficient routes for aircraft

- Decreased congestion on voice channels and provision of an alternative communications capability

- Improved NAS capacity and reduced delays associated with congestion and weather

- Improved communication accuracy and safety with digital communication (i.e., reduced read/hear back errors, reduced loss of communications events)

- Reduced environmental impact due to decreased fuel burn and emissions

- Direct operating cost savings from increased throughput realized through reduced delays and improved communications.

S1P1 Data Comm Tower Services have been readily adopted by the operators, with 13 domestic mainline air carriers, 54 international air carriers, and over 1,900 business jet and general aviation users utilizing Data Comm Tower Services across 67 different aircraft types.

In August 2019, Data Comm S1P1 Tower Services crossed over 61,000 operations per week, which is a 2,276 percent increase in operations over the past three years. As of July 2019, Data Comm

S1P1 Tower Services has cleared over six million flights (over 829 million passengers) resulting in:

- Over 1.0 million minutes of reduced delay

- Over 1.6 million minutes of communication time saved

- Over 8.9 million kilograms of carbon dioxide emissions prevented

- Over 94,100 readback errors prevented.

S1P2 Data Comm En Route Initial Services are in the early stages of field implementation and currently are available in the Indianapolis and Kansas City Air Routes Traffic Control Centers (ARTCC). So far, S1P2 En Route Initial Services has been utilized by 40 operators across 46 different aircraft types, resulting in:

- Over 20,600 minutes of communication time saved

- Over 5,400 read back errors prevented.

Segment 1 Phase 1

The primary benefits measure for this analysis was air traffic delay reduction (gate, ground, and airborne). Convective weather impact reduction benefits were examined as well.

In order to evaluate the benefits of Data Comm S1P1, specific measures were derived to capture and quantify the impact of the operational effects. The documented controller productivity efficiencies were determined to produce increased system capacity, which would yield benefits best measured in terms of delay reduction (gate, ground, and airborne).

Delay reduction results from an increase in controller communication efficiency enabled by Data Comm functionality. The controller can use this additional time to work more traffic and/or provide better service to airspace users, thus reducing delays.

In addition to the benefits described above, data communications also provides a safety benefit due to:

- Reduced number of readback/hearback errors

- Fewer stepped-on communications

- Enduring information on clearances at both the controller position and the cockpit, decreasing misunderstanding

- An alternate communication path when pilot is on the wrong frequency, there is a stuck microphone, or a radio is inoperative.

The full impact of these safety enhancements is hard to monetize, but the impact of data communications on operational errors was examined explicitly to provide quantification of a portion of these benefits.

All benefit analyses are documented in the Benefits Basis of Estimate (BOE) and in other Data Comm benefits documents and briefings.

Segment 1 Phase 2

With S1P2, Data Comm's service offerings expand into the En Route environment, modernizing the way controllers communicate with aircraft. The foundation of this transformation is the shift from an analog, voice-based communication platform to a data-driven approach that supports improvements for maintaining situational awareness. Using Data Comm, controller teams can leverage one-to-many communications and fully use the radar associate and tracker positions during periods of high volume or adverse weather. Furthermore, En Route Initial Services reduce communication time for routine and repetitive communications, allowing time to handle additional aircraft and provide advanced services. The airborne reroute and direct-to-fix message sets provided with S1P2 also improve the efficiency with which aircraft route around weather and congestion. With the improved fidelity of reroutes transmitted over Data Comm, controllers can respond more quickly and provide personalized reroutes that accommodate operator preferences better than current capabilities allow.

As performance-based navigation, advanced traffic management concepts, and time-based flow management continue to improve the NAS, Data Comm becomes even more vital. Airborne reroute and direct-to-fix message sets further improve controller flexibility to provide advanced services and more optimal routing. Frequency congestion and controller workload is further reduced through the use of Data Comm for additional routine and repetitive messages, such as advisory messages and holding instructions. In addition to the direct benefits of Data Comm and the portfolio impacts on other NextGen programs, Data Comm is a game-changer that provides the NAS with a whole new platform for innovation. The advent of a capability to uplink perfectly accurate instructions directly into an aircraft's flight management system (FMS) will transform air traffic management.

The S1P2 benefits metrics were initially validated and accepted by the JRC at the S1P1 FID in 2012 as part of the larger Data Comm business case. The benefits for En Route Services were refined and presented again as part of the S1P2 FID for En Route Initial Services in 2014, and again in 2016 at the FID for En Route Full Services. At each decision point, the JRC concluded that, in order to realize full benefits of Data Comm, both the Tower and En Route phases of the program need to be implemented.

The Data Comm En Route Services benefit estimates have been updated to support a subsequent FID for a baseline of funding for Full Services. All benefit metrics were risk-adjusted in coordination with FAA's Investment Planning & Analysis (IP&A) operations research group to account for a wide range of uncertainties in data, approach and models used. The Benefits BOE provides additional details on the methodologies for each analysis.

For the Full Services benefits update, key services were monetized, but many of the benefits were described qualitatively and supported with data on the frequency of occurrence, duration, and the safety impact.

c. Cost Estimates

Data Comm cost estimation covers all of Segment 1 - S1P1 Tower and S1P2 for all En Route activities, both Initial Services and Full Services. The life cycle cost estimates encompass design, development, test, training, and implementation of Data Comm services. Costs are grouped into the following system and functional areas:

Segment 1 Phase 1

- **ERAM Enhancements:** Includes protocol gateway (PGW) and "Log on" development, implementation, and operations and maintenance

- **TDLS Enhancements:** Includes departure clearance (DCL) development, implementation, and operations and maintenance

- **Data Comm Integrated Services (DCIS):** Includes Data Comm Network Services (DCNS), end-to-end systems integration and engineering (I&E) support, and avionics equipage

- **FAA Telecommunications Infrastructure (FTI):** Includes the necessary infrastructure for interfacility terrestrial communications

- **FANS 1/A Avionics:** includes the capabilities in the aircraft to support Data Comm services in the cockpit

- **Systems Engineering and Program Management (SEPM):** Includes all program office aspects of planning activities (program management, systems engineering, acquisition planning and management, business and financial management)

- **Test, Training, and Implementation:** Includes all non-prime contractor requirements for system test and evaluation, site implementation, acceptance and training. Air Traffic user training is included here as well.

Segment 1 Phase 2

- **ERAM Enhancements:** modifications to the ERAM system required to deliver National Single Data Authority (NSDA) functionality, En Route Initial Services and En Route Full Services

- **TDLS Enhancements:** TDLS modifications required to deliver NSDA functionality as part of the Initial Services scope

- **DCIS/DCNS:** DCIS, including integration, engineering, and test support, and DCNS, including VDL Mode 2 air-to-ground network coverage of En Route airspace

- **FAA Telecommunications Infrastructure (FTI):** Includes the necessary infrastructure for interfacility terrestrial communications

- **FANS 1/A Avionics:** includes the capabilities in the aircraft to support Data Comm services in the cockpit

- **System Engineering and Program Management:** Includes all program office aspects of planning and support activities (e.g., program management, contract management, outreach, flight standards, security, safety engineering)

- **Test, Training, and Implementation:** Includes all non-prime contractor requirements for system test and evaluation, site implementation, acceptance and training. Air Traffic user training is included here as well.

The following general ground rules and assumptions were applied across cost categories and are not specific to one cost area:

- **Inflation:** 2015 OMB inflation indices are used for all costs except for the ERAM prime vendor costs. For the ERAM prime vendor, escalation is applied based on trends in their Forward Pricing Rates combined with assumptions about shifts in labor mix as the program is executed.

- **Risk Adjustment:** Risk adjustment is conducted via Monte Carlo simulation using @RISK and assigning triangular distributions for all cost elements.

- **Acquisition:** ERAM services will be provided via contract modification to the existing ERAM contract with Lockheed Martin. The DCIS acquisition involves ordering services based on the previously negotiated DCIS contract with Harris Corporation. TDLS enhancements (for Initial Services only) will be conducted by the Interfacility Communications Engineering Team (IFCET).

All cost estimates have been prepared by FAA personnel and support staff. Cost and pricing information contained in prior vendor proposals for prior Data Comm phases, as well as information from past contract negotiations and historical vendor performance, were used in development of the estimates. Estimates were updated in May 2016 due to changes in the S1P2 En Route Full Services scope necessitated by changes in program funding levels.

d. Return on Investment Estimate

Segment 1 Phase 1

Table 6 shows the results of the economic analysis of S1P1, both with and without passenger time savings benefits included.

	Without Passenger Time Savings	With Passenger Time Savings
Net Present Value (FY12$M)	$1,049	$4,998
B/C Ratio	1.51	3.45
Payback Year	2033	2027

Table 6

Segment 1 Phase 2

The programmatic metrics were updated with the results of the Full Services benefit, cost, and schedule analysis to revise the economic metrics for Data Comm S1P2 for each equipage scenario.

Table 7 shows the results of the economic analysis of S1P2, both with and without passenger time savings benefits included.

	Without Passenger Time Savings	With Passenger Time Savings
Net Present Value (FY15$M)	$1,955	$5,295
B/C Ratio	2.52	5.13
Payback Year	2028	2026

Table 7

ERAM

a. Program Description

En Route Automation Modernization (ERAM) is the en route automation system and the foundation of the FAA ATC environment. In concert with other programs, ERAM replaced aging NAS equipment and modernized the en route infrastructure to provide an open standards-based system that will be the basis for future capabilities and enhancements. ERAM serves as the platform through which air traffic control services evolve from legacy technology, procedures, and policy to NextGen. ERAM is a secure, modular,

and expandable system that is information technology standards-based and International Civil Aviation Organization (ICAO)-compliant.

The ERAM system ingests, processes, coordinates, distributes, and tracks information on en route aircraft movement throughout the domestic and international airspace. ERAM provides automation services for the en route domain at the 20 Continental United States (CONUS) ARTCCs. ERAM support, test and training capabilities are provided at each ARTCC, as well as at the William J. Hughes Technical Center (WJHTC) and the Mike Monroney Aeronautical Center (FAA Academy). National support services, en route air traffic system maintenance and system deployment test and verification functions for ERAM reside at the WJHTC. The FAA Academy provides training services for Technical Operations and Air Traffic personnel.

The initial investment in the baseline ERAM system funded deployment to all 20 ARTCCs within the continental United States, which was completed in Fiscal Year (FY) 2015. By 2016, ERAM included the baseline functionality plus en route support for:

- Airborne and Pre Departure Traffic Flow Management (TFM) reroutes initiatives

- Air-To-Ground Tower Controller Pilot Data-link Communications (CPDLC) initiatives

- Timed-Based Flow Management (TBFM) enhancements including Ground-Based Interval Management – Spacing (GIM-S) initiatives

To accommodate NAS-wide changes described by the NextGen Implementation Plan (NGIP), the hardware and software systems that make up the ERAM platform need to periodically be upgraded and refreshed.[7]

ERAM System Enhancements and Technical Refreshment (SE&TR)

ERAM System Enhancements consisted of capabilities above and beyond core ERAM functionality. The enhancements addressed the needs identified by users of ERAM and FAA stakeholders after ERAM was deployed and became fully operational in 2015.

System Enhancements consist of the following:

- Test and Training System (TTS) improvements;

- Controller usability enhancements;

- Tracking and correlation processing enhancements; and

- Improvement of overall system management, analysis and monitor and control functions.

The Technology Refresh portion of the ERAM SE&TR program was necessary because many of the ERAM components, which were procured in 2006, were at end-of-life and required replacement.

The Initial Technology Refresh under this segment consisted of the following:

- AIX Operating System Version Update;

- En Route Communications Gateway (ECG) Router Firewall replacement;

- En Route Information Display (ERIDS) Hardware replacement;

- Support Environment Operating System replacement.

SE&TR were the first Post ORD enhancements and tech refresh for the original ERAM software

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[7]This summary is primarily based on Business Case Analysis Report for to En Route Automation Modernization System Enhancement and Technical Refreshment – September 2013, Final Business Case for En Route Automation Modernization (ERAM) Sector Enhancements (SecE Segment 1) Segment 1 – November 2016 and Final Business Case Analysis Report for ERAM Technology Refresh 2 – November 2016.

and hardware deployment. They are commonly referred to as EE1 and TR1.

A complete business case analysis was not performed for SE&TR, as it largely addressed sustainment items of the ERAM platform. Thus benefits and return on investment were not estimated. A thorough cost analysis was performed. SE&TR received Final Investment Decision for ERAM System Enhancements and Technology Refreshment in September 2013 and completed in September 2017.

ERAM Enhancements 2 (EE2)

The ERAM Enhancements 2 (EE2) investment addresses the following deficiencies[8]:

- Unacceptable levels of missed and false alerts from tactical and strategic conflict probe alerting functions. A series of improvements to reduce false alerts have been identified.

- Aircraft trajectory modeling inefficiencies result in trajectories that are not accurate enough to support NextGen PBN initiatives. This is limiting the use of Optimized Profile Descents and will restrict the agency's ability to make use of future PBN investments such as Interval Management, Dynamic RNP, and others.

- The manual process of amending the ICAO code information is cumbersome and can be work intensive for controllers. Amended ICAO code information is not being adequately maintained or entered into ERAM, creating problems of loss of Reduced Vertical Separation Minima (RVSM) / Non-RVSM and PBN (RNAV1, 2, 3 and RNP1) routing capability.

- Lack of ERAM automation support for coordination and exchange of flight data and track control with international Air Navigation Service Provider (ANSP) is limited,

adding workload burden on controllers and increasing the likelihood for human error. International Common Harmonization expands the automated coordination of flight data and aircraft control with the Canadian Air Navigation Service Provider (Nav Canada).

- ERAM periodic local adaptation changes are embedded within the national releases, leading to significant delays to the implementation of local changes.

- Lack of UAS aircraft performance characteristics in ERAM result in trajectory modeling errors ultimately increasing workload, adversely impacting situational awareness, and degrading predictability in operations.

- Increasing the information available to the National ERAM Technical Operations Team will improve their ability to diagnose and address ERAM software and hardware problems in a timely and efficient manner.

- The current automation capabilities lack the requisite accuracy, consistency, and usability needed during high demand situations for the efficient use of airspace. As air traffic levels and the need to allow more fuel efficient flight profiles increase, the Air Traffic Controllers' ability to maintain safe aircraft separation becomes a limiting factor, often resulting in the establishment of traffic restrictions that yield sub-optimal airspace capacity utilization. The need to provide new and enhanced automation assistance in the NAS to enable Air Traffic Control personnel to handle traffic growth without increasing restrictions, delays, and controller workload becomes critical.

These deficiencies affect the quality of the information available to the controllers as well as the safety and efficiency of the operational services.

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[8]ERAM SecE Segment 1 is now referred to as ERAM Enhancements 2.

ERAM Sustainment 2 (ES2)

The ERAM Sustainment 2 (ES2), scheduled for Calendar Year (CY) 2018, addresses high priority ERAM sustainment issues.[9] Namely, it addresses key sustainment risks that stem from the current critical ERAM display subsystem equipment end-of-service life and technology obsolescence, as well as backroom flight data processing capacity limitations.

ES2 includes the following key system updates:

- Replace IBM Power PC/RISC processors that drive ERAM displays with new x86-based processors

- Replace existing analog Barco radar position flat-panel monitors and graphical processing units (GPUs) with digital displays and video graphics cards

- Refresh Keyboard/Video/Mouse (KVM) switch to support transition to digital display

- Migrate AIX Operating System (OS) to Linux

- Add supplemental servers to augment Flight Data Processing (FDP) and Surveillance Data processor core.

Within the 20 ARTCCs, the Display System (DS) subsystem function provides the interface with other ERAM subsystems and provides a consistent and accurate picture of local and surrounding airspace with respect to aircraft traffic, weather conditions, and airspace characteristics. Each ARTCC breaks its blocks of airspace down into smaller sectors. Controllers use Radar (R-Position) and Data (D-Position) to control traffic in sectors.

The (R) and (D) Positions at ARTCCs are currently powered by IBM Power PC/RISC processors. IBM no longer manufactures the RISC processor, so these particular parts will have to be upgraded as supply stocks eventually run out. Compounding this end-of-life issue is the observed exponential

increase in failure rates for the backplane spare. This in turn could affect the continuity of ATC operations because (R) and (D)-Position would no longer display information, interfering with the most basic aircraft separation function of ATC.

A replacement of IBM-based processors with new Hewlett Packard Enterprise (HPE) Proliant Modular Line (ML-30) processors, that have projected long-term supply availability, was required. Other peripherals (KVM accessories, record/playback technology) will also be upgraded as part of the processor swap in support of the transition from an analog to digital display.

Additionally, the Barco high resolution GPUs that are critical to the display of air traffic information on the controllers' situation display are no longer produced or supported by the vendor as of August 2016. The 20" x 20" BARCO analog monitor will be replaced with the E210 43" Ultra High Definition (UHD) monitors.

Finally, the backroom processors are facing a capacity shortfall. As new data sources are ingested by ERAM as part of the NextGen updates, additional backroom processing capacity will be required. An additional argument for including these in this Tech Refresh is provided by the recent observed increase in failures in the field.

A complete business case analysis was not performed for ES2, as it only addressed sustainment items of the ERAM platform. Thus benefits and return on investment were not estimated. A thorough cost analysis was performed.

b. Benefit Estimates

ERAM Enhancements 2 (EE2)

The benefits of ERAM Enhancements 2 are broken up by the six capability areas:

1. Trajectory Modeling and Conflict Probe Enhancements

2. Flight Plan Processing improvements

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[9]ERAM TR2 is now referred to as ERAM Sustainment 2.

3. International Common Harmonization (with NAV Canada)

4. Adaptation Refinement

5. Incorporation of UAS Operational Performance

6. Continued support of Technical Operations Problem Trouble Reports (PTR)

Each capability is broken up into several sub-capabilities; for the most part the benefits at the lower level were not addressable due to significant overlap and dependencies. This includes significant and complex software changes and procedures. These changes were proposed and recommended as beneficial to the ERAM users (controllers, trainers), FAA HQ, and international ANSP partners.

Ground Rules and Assumptions

- Most benefits will accrue starting with the final year of implementation in 2024, with ANSP (Nav Canada only) harmonization providing initial benefits in 2022

- Life-cycle benefits are from FY24 to FY33, with 10 full years after final IOC (mid-FY23)

- All ADOC, PVT, Inflation, and other economic factors are applied based on the August 2015 factors provided by IP&A

- Traffic forecasts are provided by the FAA Policy Office (APO) Terminal Area Forecast (TAF) and AJR-G1 (detailed schedules)

- Risk adjustment of the future traffic demand is done based on IP&A guidance using a triangular distribution on demand growth (0, 50, and 100 percent) applied to the TAF.

c. Cost Estimates

ERAM SE&TR

Program life-cycle costs for ERAM System Enhancements and Tech Refresh were estimated from FY14 to FY17. The last funding year for the SETR program was Fiscal Year 2016 and implementation completed in 2017. The FAA standard Work Breakdown Structure (WBS), version 5.0 is utilized to model these costs. Costs for each WBS element were estimated using Base Year 2013 (BY13) dollars, then time phased and inflated using the latest OMB inflation indices to calculate the Then Year (TY) point estimate. The Life-Cycle Cost estimate was then risk adjusted with an 80 percent Confidence Level.

Only F&E costs are included in the SETR estimate. The existing O&M baseline funds are expected to cover the maintenance of the ERAM program, hence there are incremental O&M costs to the existing ERAM O&M baseline throughout the operational life cycle.

A variety of estimating methodologies were used to derive the point estimate. The following paragraphs summarize the various techniques and data sources used to estimate the cost elements and calculate the life cycle estimate:

Hardware: The ERAM System Enhancement and Tech Refresh hardware estimate was based on a component buildup from the vendor. The hardware components consist of: (1) AIX Operating Systems Upgrade, (2) ECG Router Firewall, and (3) ERIDS Hardware & non repairable components. The prime developer proposed several hardware options to the FAA, and an Independent Government Cost Estimate (IGCE) was developed based on those options. The Program conducted proposal solicitation, evaluation, negotiation, and contract award, and followed all Acquisition Management System processes to ensure procurement integrity.

Software: The ERAM System Enhancement and Tech Refresh hardware estimate was based on a Source Lines of Code (SLOC) estimate provided by the developer during the request for proposal phase. A list of the functional need requirements was provided to the prime developer during the Request For Proposal. The prime reviewed and

provided an assessment of the amount of SLOC necessary to deliver those functions in their proposal with detail work necessity. The cost per line was derived based on actuals from the existing ERAM program.

Program Office Federal and Support Contractor labor: Program office Federal and Support contractor labor estimates were based on FY13 ERAM staffing levels and the work plan provided by the program office. Past and current actuals were then used to project future costs such as program management, systems engineering, second level engineering, training and logistics planning. The support contractor labor rate was set based on the existing actual labor rates. Federal salaries were based on the Government Service schedule for estimating purposes and adjusted by the standard benefits factor.

ERAM Enhancements 2 (EE2)

Ground Rules and Assumptions

- The Life Cycle Cost Estimate analysis timeframe is from FY17-FY23.

- The existing O&M baseline funds will cover the maintenance of this program. No additional O&M funding is required for Preventive Maintenance, Corrective Maintenance, Logistics, Telecommunications, and Utilities.

- Software costs are estimated using an $1,870 cost per SLOC, which is based on historical data of the recently completed ERAM builds and cross-checked against other program proposals from the same vendor.

- Technology Refreshment is not part of the scope for the EE2 program, hence no costs are included for any tech refresh hardware or activities.

- Program Office (PO) and Support Contractor costs for the program are included in the

estimate. These levels of effort estimates are based on staffing levels on current contracts, and adjusted for the EE2 needs.

- Training development costs are included in the cost estimate via the SLOC metric, and are not shown separately.

- No additional training conduct costs are expected. Training will follow the current ERAM release training which consists of briefing packages developed by the prime contractor and administered using the FAA Electronic Learning Management System (ELMS), which is at no additional cost.

- Second Level Engineering (SLE) prime contractor activities in support of the EE2 work are included in the SLOC metric. Historical data shows that this work is accounted for in the SLOC metric through the prime vendor Contract Line Numbers (CLINs).

- It is assumed that additional software maintenance costs will not be necessary due to the commonality of the code being added. Hence no impact to software maintenance is expected.

- A risk analysis was performed using a Monte-Carlo simulation in the Crystal Ball risk tool. Variables on which risk was applied include SLOC cost, SLOC quantity, hardware cost, all salaries, and travel.

Program life-cycle costs for EE2 are estimated from FY17 to FY22. The FAA standard WBS, version 5.1 is utilized to model these costs. Cost for each WBS element is estimated using Base Year 2016 (BY16$) dollars, then time-phased and inflated using the latest OMB inflation indices to calculate the Then Year (TY) point estimate. The Life-Cycle Cost estimate was risk adjusted with an 80 percent confidence level.

ERAM Sustainment 2 (ES2)

The cost estimate analysis timeframe is FY17-FY21. All prime costs were based on the proposal submitted by Leidos in July 2016. Prime contractor costs include the costs to procure the hardware needed for technology refreshment, associated installation, deployment, training, engineering, travel, and software upgrades.

With the exception of the larger R-Position Display, Tech Refresh will not introduce "look and feel" changes for ATC users and will minimize the "look and feel" changes for other users such as Tech Ops. Tech Refresh will provide equivalent function and capacity to that which is available today. There are no functional or performance requirements for TR2. Any improvements to baseline capabilities/performance are solely based on the technology advances of the new equipment.

ERAM implements ES2 in a two-phase deployment approach:

- **Early D:** an accelerated deployment to address Display Processor Sysplanar Board failures. Replaces D-Position processor with new Linux Operating System HPE ML30

- **Full Deployment:** replaces the R-Position Processor, Keyboard Video Monitor (KVM) and display at all 20 ARTCC and the FAAAC

The prime contractor will develop the training courses and deliver the training, and one day of controller orientation will be provided on the larger R-Position monitor. The associated costs are included in the proposal. Air Traffic Controllers will see no appreciable change in form or function as a result of Tech Refresh. Air Traffic Controllers do not need additional training. Non-prime costs include government FTEs and support contractors and their travel.

Contractor salary rates are based on existing contracts, and cover travel costs since they are based on the total cost of the contract, which includes travel. The existing ERAM O&M baseline funds are expected to cover the maintenance of this program. No additional Operations funding is required for Preventive Maintenance, Corrective Maintenance, Logistics, Telecommunications, and Utilities.

d. Return on Investment Estimate

ERAM Enhancement 2 (EE2)

An economic analysis using the FAA Economic Analysis Tool (FEAT) was performed for each capability that has monetized benefits. FEAT performs a statistical analysis combining cost and benefits to create metrics (e.g., B/C ratio, NPV, etc.) at the selected confidence level (typically 80 percent).

The inputs include the uncertainty ranges around the total cost and benefits, typically a Cumulative Probability Distribution (CDF) in 5 percent increments, along with the annualized cost & benefits. The process runs a Monte-Carlo simulation with a default of 5,000 iterations. Economic Analysis guidelines on the IP&A Website provide the methodology utilized.

Table 8 provides a summary of the total program ROI metrics. As shown, the overall B/C ratio is 0.39, however several of the EE2 capabilities are infrastructure-related, with no monetized benefits. The one primary monetized capability (Trajectory & Conflict Probe enhancements) shows significant returns: B/C ratio of 1.05, net present value of $3M, payback in 2033, and an internal rate of return of 7.7 percent.

Net Present Value (FY18$M)	$ -113.00
B/C Ratio	0.39
Payback Year	N/A

Table 8

e. Changes from Previous Estimates

In December 2018, an updated version of the BCAR report[10] was developed for ERAM SecE Segment 1, now referred as ERAM Enhancements 2. Cost and benefit values had been adjusted using baseline year 2018. Table 8a provides a summary of the adjusted ROI metrics.

Net Present Value (FY18$M)	$-156.47
B/C Ratio	0.06
Payback Year	N/A

Table 8a

NWP

a. Program Description

NextGen Weather Processor (NWP)[11] will establish a common weather processing platform that will consolidate weather product generation from legacy weather processing systems, and will produce new advanced aviation specific weather products to benefit ATC users. NWP will improve the weather information needed by decision makers and DSTs to help improve flight efficiency, provide the opportunity to increase the capacity of air transportation operations, and increase the margin of Air Traffic (AT) safety. NWP will help reduce operations and maintenance costs by consolidating weather processing functions, enabling the decommissioning of Corridor Integrated Weather System (CIWS), Integrated Terminal Weather System (ITWS), and Weather and Radar Processor (WARP).

NWP will generate consistent weather products that will provide real-time, expanded, and more accurate geographic coverage to a wider range of users. NWP will produce advanced aviation weather data, including long-lead weather products (up to eight hours), Convective Weather Avoidance Fields (CWAFs), flexible floor weather mosaics, and more timely weather products with higher accuracy. NWP will perform weather translation, an automated feature that identifies potential weather constraints in a format understandable to non-meteorologists and ingestible directly into automated NextGen DSTs. The users of the NWP weather products will be traffic flow managers, supervisors, DSTs, ANSPs, AT controllers, and the aviation community.

NWP will transition advanced prediction capabilities from the latest aviation weather research into operational use by producing rapid analysis and frequently updated, accurate convective weather products useful for both tactical and strategic AT management. NWP will improve the utility of convective weather information by extending it further into the planning period (up to eight hours), and by providing better information on individual weather hazards caused by convection (e.g., low-level wind shear and micro bursts).

NWP will produce accurate analyses (e.g., mosaics) and predictions for all operational uses within the AT community, significantly reducing the potential for conflicting convective information from a variety of sources. NWP will provide users of the NAS with accurate convective weather information upon which to base decisions.

NWP will provide weather products enabling the controller to better manage sector volume/complexity, route capacity, and aid in balancing controller workload. The weather information provided by NWP will greatly serve the needs of Traffic Flow Management (TFM) by decreasing the need for such TFM programs as altitude restrictions, miles-in-trail restrictions, speed restrictions, airborne holding, sequencing programs, reroutes, ground delay programs, and ground stops. DSTs using NWP products include TFMS/Route Availability Planning Tool (RAPT) and TBFM.

[10]Final Business Case for En Route Automation Modernization (ERAM) Enhancements 2 (EE2), December 2018.
[11]This summary is primarily based on Final Business Case for NextGen Weather Processor (NWP) Version 1.2, 9/9/2014.

NWP will support the Convective Weather Avoidance Model (CWAM) and the determination of Weather Avoidance Fields (WAFs). These automated applications will enable the traffic flow manager to identify airspace that is not impacted by severe weather, thus permitting the optimization of reroutes, while maximizing AT capacity and efficiency of operations.

NWP will expand the availability of real-time weather information in support of the collaborative decision-making process and the concept of common situational awareness, primarily through the implementation of a Web display. The Airline Operations Centers (AOCs), flight dispatchers, airport authorities, airlines, as well as general aviation will have access to the NWP weather products. The availability of NWP weather information will lead to increased capacity, flight efficiency, and enhanced safety within the NAS.

b. Benefit Estimates

NWP will replace/consolidate legacy weather processor systems into a single weather processing platform with advanced capabilities. NWP will produce advanced aviation specific weather information and will integrate NWS forecast models with real-time radar extrapolation to produce convective weather products out to 8 hours. NWP will also perform weather translation that will be used by DSTs. NWP will translate analysis and predictions into airspace constraint information that decision makers and DSTs will use to determine if and when adverse weather will impact airspace and/or airport operations. These enhanced capabilities will produce a greater situational awareness of the timing, location, and severity of weather that will allow controllers to more efficiently manage air traffic around weather hazards and improve safety by reducing the number of encounters with weather hazards. NWP benefits accrue in the following categories:

- Improved NAS-wide routing/resource convective weather impact management

- Improved Airspace Flow Program (AFP) execution/management

- Enhanced Playbook reroute planning/execution

- Improved DST performance from the integration of NWP data

- Improved planning of airport utilization surrounding winter weather events

- Improved operational ATM decision-making from enhanced access to weather products (technology/display)

- Enhanced weather products leading to reduced weather accidents

- Legacy system cost avoidance.

The NWP benefits analyses relied upon a number of programmatic assumptions and ground rules including:

- The business case lifecycle for NWP is from FY2014 to FY2040, to reflect a 20-year post implementation lifecycle.

- Safety benefits are quantified in terms of projected accidents and monetized using FAA standard values for avoided fatalities, injuries, and aircraft damage.

- Flight efficiency benefits are quantified in terms of delay reduction and/or reduction in cancellations and diversions. These metrics are monetized (unless otherwise stated) using FAA standard treatment of PVT plus ADOC which considers the cost of fuel, crew, and maintenance.

- Delay avoidance will grow at least linearly in proportion to traffic growth. Projected growth in traffic was obtained from the FAA Terminal Area Forecast (TAF) issued February 2014, although growth predicted by the TAF after 2025 was not applied.

- Weather patterns do not change over the NWP lifecycle.

The NWP Final Investment benefits analysis utilized a separate approach to estimate each benefit area. There are several benefits categorized into three main elements: flight efficiency, safety, and legacy system cost avoidance. The flight efficiency benefits are quantified in terms of fuel savings and/or delays (airborne, ground, gate) and monetized using values for fuel cost, ADOC, and PVT. Changes in the number of cancellations and diversions were also quantified where applicable and monetized using standard values. The safety benefits are quantified in terms of projected accidents and monetized using values for avoided fatalities, injuries, and aircraft damage. The legacy system cost avoidance benefits are derived from the cost analysis. All benefit metrics were risk-adjusted in coordination with FAA's Office of Investment Planning and Analysis (IP&A) to account for a wide range of uncertainties in data, approach and models used.

c. Cost Estimates

The NWP life-cycle cost estimates encompass the period starting in FY 2014 and ending in FY 2040. The FAA standard Work Breakdown Structure (WBS), version 5.1, was utilized to model the costs. Each WBS element within the cost estimates was estimated in Base-Year 2014 dollars, time phased, and inflated using the latest OMB inflation indices to calculate the Then-Year point estimate. Risk analysis was then performed to calculate the High Confidence Life-Cycle Cost estimate for the Legacy Case and the new system.

The NWP investment consists of a Facilities and Equipment (F&E) and an Operations and Maintenance (O&M) component. These costs include the costs of materials and Contractor/Federal labor required to develop, test, and support the NWP system. The F&E component breaks out FAA labor as its own cost element, with the rest consisting of contractor labor and materials costs. The support contractor labor rate was based on the analogous

FAA Program Office labor costs. Federal salaries were based on the Government Service schedule for estimating purposes and adjusted by the standard benefits factor. Risk analysis was performed to calculate the High-Confidence Life-Cycle Cost estimate for the Legacy Case and the point estimate.

Cost inputs for non-prime contractor costs were provided by other organizations within the FAA. Level of effort inputs for Testing and Second Level Engineering activities were provided by persons within the appropriate departments within the FAA's Technical Center. Implementation costs for the system were based on input from Engineering Services and implementation SMEs. Logistics support costs (Federal and Support Contractor) were provided by Logistic SMEs.

A contractor will provide software/hardware maintenance support not only through full deployment of the system, but also for the remainder of the lifecycle. The FAA's Second Level Organization role is that of oversight and support for software maintenance. The FAA's TechOps will oversee the maintenance of the associated hardware.

The Prime contractor costs for the solution were based on the successful offering of the NWP competitive procurement. These costs were provided in twenty independent Contract Line Item Numbers (CLINs). These costs were then mapped into the appropriate NWP WBS elements for F&E and Operations and Support (O&S) costs. Prime Contractor activities will include Hardware Procurement, Software Development, Testing, Implementation, and In-Service maintenance (Corrective Maintenance, Logistics and 2nd Level Engineering).

The costs associated with the winning vendor's bids were much lower than the IGCE. The reason for this difference is that the IGCE assumed the vendor would have a far greater amount of software development and testing to perform. However, the selected proposal is leveraging a

significant amount of previous work and a large amount of commercial-off-the-shelf items.

d. Return on Investment Estimate

Using the results of the benefits analysis and the completed cost estimate, programmatic metrics were calculated to determine the financial returns for the NWP System. The costs and benefits in the tables below are in discounted present value (PV) units to facilitate comparison across alternatives. The business case lifecycle is from 2014 to 2040.

The cost and benefit values represent a "high confidence" estimate from an underlying distribution of possible cost and benefit outcomes. In order to obtain similarly "high-confidence" economic analysis metrics, the full distributions of costs and benefits were statistically combined using a Monte Carlo simulation. These statistically combined results are presented in Table 9. The statistical combination of the cost and benefit distributions results in a different NPV and B/C ratio than would result from simply subtracting the "high-confidence" risk-adjusted present value costs from the risk-adjusted present value benefits or from taking the ratio of the two values. Generally, the statistically combined NPV and B/C ratios will be slightly larger, as lower cost and higher benefit values from the rest of the distributions are included in the final estimate.

Net Present Value (FY14$M)	$918.0
B/C Ratio	5.88
Payback Year	2021

Table 9

If all quantified benefits are included, NWP results in a NPV of $918 million, a benefit-cost ratio of 5.88, and a payback period of two years after Initial Operating Capability (IOC).

e. Changes from Previous Estimates

The NWP Program is undergoing a re-plan due to a delay in the implementation associated with the interdependencies with CSS-Wx and completion of software development. As part of the re-plan, the program is determining cost and schedule impacts.

SWIM

a. Program Description

The System Wide Information Management (SWIM) Program[12] is an advanced technology program designed to facilitate greater sharing of ATM system information with far less expense and complexity than required by current methods. SWIM supports NextGen goals by facilitating its data sharing requirements and improving the way the FAA creates and leverages new and existing systems in the NAS. SWIM enables increased common situational awareness and improves NAS agility to deliver the right information to the right people at the right time.

SWIM is transforming NAS application interfaces from tightly coupled, point-to-point interfaces into a Service Oriented Architecture (SOA) by deploying common software throughout the NAS that allows interfaces to be re-used, by improving information security and supporting responses to new security initiatives, and by facilitating data integration through SWIM Governance. SWIM-enabled systems will have the ability to request and receive information when they need it, subscribe for automatic receipt, and publish information and services as appropriate.

SWIM will leverage existing systems and networks to the extent practicable, and be based on technologies that have been proven in both operational and demonstration environments to reduce cost and risk. SWIM will be developed incrementally

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[12]This summary is primarily based on Business Case Analysis Report for System Wide Information Management (SWIM) Segment 1, 6/14/2007; Final Business Case Analysis Report for System Wide Information Management (SWIM) Segment 2A, 7/3/2012; and Final Business Case Analysis Report for System Wide Information Management (SWIM) Segment 2B, 11/16/2015.

based upon the needs of various data communities and maturity of concepts of use, and will be developed in segments that are sized to fit reasonable cost, schedule, and risk thresholds.

In each segment, a set of NAS enterprise services is developed and enterprise infrastructure is added to support the implementation of capabilities associated with the segments.

Segment 1

SWIM Segment 1 includes the following participating programs: ERAM, TFMS, Terminal Data Distribution System (TDDS), Integrated Terminal Weather System (ITWS), Corridor Integrated Weather System (CIWS), AIMM, and Weather Message Switching Center Replacement (WMSCR). These programs will develop and deploy SWIM capabilities in accordance with the SWIM Program Requirements and in accordance with SWIM Governance; however, SWIM does not impose new development or management strategies on the programs. The development of SWIM capabilities is in accordance with each program's existing strategies.

SWIM Segment 2A

The Segment 2A approach is based on the need to satisfy midterm (FY 2012-2016) NextGen Operational Improvements (OIs). As detailed in the Implementation Strategy and Planning Document (ISPD), Segment 2A includes the following key elements:

- Development, deployment, and maintenance of SOA Core Services comprised of Enterprise Messaging, Enterprise Service Management, Interface Management, and Security services

- NAS SOA Governance

- Acquisition, management and maintenance activities for the hardware and software associated with developing and deploying those capabilities that will result in a consolidated SOA infrastructure.

Programs subscribing to Segment 2A capabilities are responsible for development of their SWIM compliant services. Hardware and software associated with SOA capabilities hosted outside the SWIM consolidated infrastructure will be the responsibility of the stakeholders hosting the capabilities.

SWIM Segment 2B

SWIM Segment 2B builds upon the capabilities and functionality developed and implemented by previous SWIM Segments. The existing capabilities will continue to provide data products and service-oriented architecture functionality.

SWIM Segment 2B will provide four capabilities. These capabilities include two systems categorized within the Enterprise Architecture (EA) as support services. The remaining two are categorized as either an Enterprise Service management or Technical infrastructure capability:

- Support services capabilities:

  ○ SWIM Terminal Data Distribution Service (STDDDS phase 2)

  ○ NAS Common Reference (NCR).

- Enterprise service management service capability:

  ○ Enterprise Service monitoring (ESM).

- Technical infrastructure Service capability

  ○ Identify and access management (IAM phase 2).

b. Benefit Estimates

Segment 1

Today's hard-wired infrastructure and systems cannot readily support the addition of new data, systems, data users, and/or decision makers as NextGen requires. In general, they are connected directly to support yesterday's decision making needs. Each of these interfaces is custom designed,

developed, managed, and maintained individually at a significant cost to the FAA. NextGen relies upon a new decision construct that brings more data, systems, customers, and service providers into the process. Data will be needed at more places and for more purposes, and it must be made available in a timely manner in common formats and structures to ensure consistent use. These new "data customers" need to be accommodated by providing the governance and policy that tells them how to connect to existing, open interfaces instead of designing, developing, testing, and implementing new ones from scratch. Network technology and data management software must use commercial equipment and current industry standards, reducing developmental and upgrade costs and simplifying maintenance. Today's point-to-point architecture does not support these goals. This situation represents a performance gap that must be bridged for NextGen to be successful.

SWIM Segment 1 includes no user benefits – rather, the business case depends on the avoided costs and FAA cost savings realized by deployment of SWIM capabilities. The main cost avoidance comes from TFM RVR Data Interface, Host/ATM Data Distribution System (HADDS), Flight Data Input/Output (FDIO) and ERAM/TFM Data Exchange.

SWIM Segment 2A

Quantified SWIM benefits are exclusively in the domain of FAA cost avoidance. Benefits are estimated based on the assumption that the services in the FAA Enterprise Services Roadmap must be provided and the products of those services must be shared with multiple programs, both inside and outside of the FAA. SWIM's role is to provide the enterprise infrastructure core service capabilities needed to share this information. This leads to cost avoidance by creating an efficient, governed communication infrastructure instead of program specific interfaces. Those program specific interfaces would be developed in isolation by individual programs that, for purposes of interoperability, would likely require future rework as new

requirements for data exchange evolve or require multiple, point-to-point interfaces if there were no Enterprise message switching capability.

With or without SWIM Segment 2A, the FAA will need to increase the amount of data exchanged and the number of connections between systems as the agency moves toward NextGen. The Reference Case acknowledges the costs that the agency would incur if SWIM Segment 2A did not exist, but the data provided by NextGen programs still needs to be made available to other NAS Programs and non-NAS communities.

The NAS programs and estimated number of services that were used as a basis for the cost estimate are identical between the Reference Case and the Preferred Alternative. The cost difference between the Reference Case and Preferred Alternative results from the increased cost burden that individual programs would incur if they did not have access to an enterprise solution that allows for a more efficient development and implementation of the required data exchange between the planned services.

SWIM Segment 2B

SWIM Segment 2B capabilities provide cost avoidance benefits by deploying services identified in the FAA Enterprise service roadmap and providing them to multiple producers and consumers. This relieves individual producers and consumers from the need, and thus costs, to develop, implement and support these services in isolation.

In Segment 2B, monetized benefits are associated with this cost avoidance. The Segment 2B IAM and NCR capabilities provide significant cost avoidance benefits. To the extent possible, cost avoidance estimates have been calculated based on knowledge gained with regard to the SWIM Segment 2B cost estimates.

STDDS Phase 2 and ESM benefits have not been monetized. STDDS Phase 2 provides insignificant telecommunications cost avoidance benefits. STDDS Phase 2 has been addressed in Segment 1.

In Segment 2B STDDS Phase 2 supplements its Segment 1 benefits by enabling current customers of terminal data products to reduce their telecommunications costs by adopting SWIM.

ESM, as an infrastructure capability, does not provide monetized benefits. ESM is integrated with NEMS and contributes to the SWIM Segment 2A NEMS benefits and service objectives.

NCR cost avoidance benefits derive from relieving the TFM, TBFM, TFDM and FSS systems from the requirement to develop a capability to generate tailored, filtered, cross-domain data products.

IAM Phase 2 cost avoidance benefits result from 49 locations adopting the IAM Phase 2 capability, thereby avoiding the cost to independently develop similar security capabilities.

c. Cost Estimates

Segment 1

SWIM support to the participating programs assumes existing management structure and, for ongoing programs such as ERAM and TFM-Modernization, SWIM costs include only the *incremental costs* of development and deployment of SWIM capabilities.

The SWIM Investment Analysis Team (IAT) developed F&E cost estimates using three different methodologies:

- Staffing Build-up: subject matter experts from the participating programs provided "bottom up" cost estimates based on actual experience with the Program.

- Vendor quotes: software and hardware costs were estimated based on vendor quotes, GSA pricing, and prices for products identified on a vendor's internet site.

- Historical: costs were estimated based on historical record of costs required to develop new capabilities under the AIM, ITWS, CIWS, and WMSCR Programs.

Costs were inflated using the OMB's latest published inflation rates (January 2007). FAA labor rates were inflated 5 percent annually. In addition, costs were risk-adjusted by WBS to reflect the uncertainties of SWIM design and development.

Core Services for SWIM will be supported via a commercial software package. The package selected for estimating purposes is provided by TIBCO. The cost of procuring an Enterprise License Agreement (ELA) from TIBCO in FY10 is included in the SWIM Cost Estimate, with maintenance costs included in all successive years. In FY09, the costs for development licenses for these products are included in the Cost Estimate. The SWIM program office will provide the required software to each participating program, along with necessary training and documentation. Maintenance of the ELA is the responsibility of the SWIM Program Office.

Any additional user training required for Segment 1 capabilities has been identified and included in the SWIM Cost Estimate. Training is the responsibility of the participating program and will be conducted in accordance with existing Training Development Plans and Integrated Logistics Support Plans.

Costs to perform a Tech Refresh of the SWIM Segment 1 hardware are included in the cost estimate. These costs assume that a Tech Refresh is performed every five years.

SWIM Segment 2A

The SWIM Segment 2A cost estimate is based upon a proposal from the Harris Corporation to a FAA Request for Proposal (RFP) dated February 20, 2012. Additional costs include SWIM program office resources and telecommunications.

The Base Year cost estimate covers the years FY11 through FY16 for F&E costs and FY11 through FY33 for O&M costs.

The cost estimate uses FY12 as the Base Year. Four escalation rates are in effect: FAA compensation is escalated at 3.9 percent per year per IP&A guidance; support contractor costs are escalated using OMB guidance (generally 1.6 to 1.8 percent each year); Harris contract costs are escalated at the rate of 3.2 percent for contract items dated 2011 and prior (Domain Name Service and Network Time Protocol) and 3.0 percent for contract items dated 2012 and after (NAS Enterprise Messaging Service).

SWIM Segment 2B

The SWIM Segment 2B Investments Analysis Team (IAT) developed life cycle cost estimates for the preferred alternative using Excel and Crystal Ball. Individual cost estimates were prepared for each Segment 2B capability and the SWIM program management office (PMO) and costs funded by other FAA programs.

The SWIM PMO provided requirements to the system integrators, Volpe National Transportation Systems Center and WJHTC, to develop system architectures for each individual capability. Architecture costs were then estimated. Estimates for commercial hardware and software items were developed using vendor quotes. Software development cost was estimated using parametric models based on SLOC counts for the software architecture provided. Each estimate includes support contractor costs, FAA labor, and associated non-labor costs (for example travel).

The IAT organized all costs in accordance with FAA WBS version 5.1. Costs were inflated using OMB inflation rates for 2015 except for FAA Federal employees, which used an annual inflation rate of 2.25 percent as recommended by the FAA Office of Labor Analysis, and on-ramping and telecommunications costs covered by the FAA FTI contract, which includes a contractual rate of 3 percent.

Costs were risk adjusted by WBS, using risks developed by the Risk, Issues and opportunities (RIO) team and estimated uncertainties. The RIO team developed risks for each Segment 2B alternative.

In addition to incorporating the potential impacts of program risks on costs, uncertainty ranges and probability distributions were applied to the quantitative inputs of each cost model. For example, even though the estimates use vendor quotes and published catalog costs, the quotes will expire years before the orders are placed. Hence there is uncertainty with respect to future hardware costs independent of inflation. This uncertainty extends to the expected value of the cost impacts of program risks, in as much as these are expressed as ranges.

d. Return on Investment Estimate

Segment 1

The economic analysis, summarized in Table 10, includes calculation of the B/C ratio, NPV, and payback period for this investment. The analysis was based on risk-adjusted, then-year cost and benefits (avoided costs and cost savings) estimates. Per guidance from OMB provided in January 2007, a discounting factor of 5.1 percent was applied to the FAA avoided costs and cost savings. There are no user benefits claimed for SWIM Segment 1. Also, inflation rates were used in accordance with the guidance provided by OMB in January 2007. (All calculations use 2007 as the base year.)

Net Present Value (FY07$M)	$ 271.8
B/C Ratio	1.7
Payback Year	2010

Table 10

SWIM Segment 2A

The economic analysis, shown in Table 11, includes calculation of the B/C ratio, NPV, and payback period for this investment. The analysis was based on risk-adjusted, then-year cost and benefits (which consisted of avoided costs) estimates. Per guidance from OMB, a discounting factor of 3.5 percent was applied to the FAA avoided costs.

There are no user benefits claimed for SWIM Segment 2A. Also, inflation rates were used in accordance with the guidance provided by OMB in February 2012. (All calculations use 2012 as the base year.)

Net Present Value (FY12$M)	$104.8
B/C Ratio	1.2
Payback Year	2016

Table 11

SWIM Segment 2B

The SWIM Segment 2B economic analysis, shown in Table 12, includes calculation of the B/C ratio, NPV, and payback period for this investment. The analysis was based on risk-adjusted, then-year cost and benefits (which consisted of avoided costs) estimates. A discount rate of 7 percent was applied to the FAA avoided costs. There are no user benefits claimed for SWIM Segment 2B.

Net Present Value (FY15$M)	$51.0
B/C Ratio	1.3
Payback Year	2025

Table 12

TBFM

a. Program Description

Time Based Flow Management (TBFM)[13] is a vital part of the NAS and a key component of NextGen. It enhances air traffic operations by reducing delays and increasing efficiency of airline operations. The TBFM system, which evolved from the earlier Traffic Management Advisor (TMA), is a currently available ARTCC-based decision support tool that enables the use of time-based metering to optimize the flow of aircraft as they approach and depart congested airspace and airports.

For arrivals approaching a congested airport, TBFM determines how the multiple streams of incoming flights can be sequenced and scheduled to fully utilize the runway and other airport resources while avoiding unnecessary delay and complying with all operational constraints. For departures, TBFM schedules departure times that blend the flights into slots in the traffic flows through departure fixes or other metering points in en route airspace.

TBFM is deployed to all twenty domestic ARTCCs, where it provides arrival services for the thirty-five largest NAS airports. Its schedule timelines and traffic plan views are installed in the Traffic Management Units (TMU) at each ARTCC, and are provided to one or more Terminal Radar Approach Control (TRACON) facilities and towers associated with each ARTCC.

TBFM is also a key Traffic Flow Management (TFM) decision support tool in use at the Air Traffic Control System Command Center (ATCSCC). In its National Traffic Management Office, the ATCSCC has operational TBFM displays from all of the ARTCCs. TBFM also provides flight plan information and associated metering data to external entities.

TBFM WP2 and Enhancement 1 (formerly known as TBFM WP3)

The FAA's AJM-2 has the mission to extend the capabilities of the TBFM system. Beginning in 2010, enhancements began under TBFM WP2 to evolve the earlier TMA into the current TBFM system. A new generation of enhancements is now planned under TBFM Enhancement 1 to further expand the role and scope of time-based metering operations to provide its benefit more broadly throughout the NAS.[14] TBFM Enhancement 1 adds new capabilities that will:

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[13]This summary is primarily based on Business Case Analysis Report for TBFM – April 2010 and Business Case Analysis Report for TBFM WP3 – May 2015.
[14]TBFM WP3 is now referred to as TBFM Enhancements 1.

- Extend the scheduling capability into the terminal area through new Terminal Sequencing and Spacing (TSAS) tools provided to terminal controllers and traffic managers at nine sites

- Expand the deployment of the Integrated Departure/Arrival Capability (IDAC), begun under WP2, to an additional five Centers and additional airports.

TSAS provides arrival management guidance to TRACON controllers consistent with the schedule that en route controllers are striving to attain at arrival meter fixes. TSAS uses published definitions of Standard Terminal Arrival Routes (STARs) and approach procedures as the basis for its sequencing and scheduling. With TSAS, more precise arrival delivery can be achieved.

Furthermore, Required Navigation Performance (RNP) Radius-to-Fix (RNP-RF) approaches are anticipated to become more available. These curved paths provide increased efficiency. TSAS will enable controllers to accommodate RNP-capable aircraft along those procedures while efficiently managing non-RNP capable aircraft, even during high-traffic periods.

IDAC automates the approval request process between Air Traffic Control Towers (ATCT) and ARTCC TMUs. IDAC provides for the identification of flights requiring TBFM departure scheduling and graphic depictions of available departure slots. IDAC provides situational awareness to ATCTs so that they can select from available departure times, request a release time, and plan their operation to meet these times. This situational awareness will be provided for various TBFM environments, including a standard single departure fix and departures merging into an overhead flow.

IDAC supports traffic managers at ATCT facilities, TRACON facilities, and ARTCC facilities. Traffic managers can also use IDAC at the ATCSCC to monitor TBFM assigned delays at departure airports across multiple system constraints. IDAC provides traffic managers access and insight into scheduling of a departure into TBFM's arrival and departure capabilities through common situational awareness, decision support, and the ability to automate phone-based communication.

b. Benefit Estimates

TBFM WP2

TBFM provides automation, communication, and decision support tools to:

- Increase efficient use of existing capacity

- Reduce manual workload

- Increase common situational awareness

- Reduce delay in the terminal and en route airspaces.

TBFM capabilities provide additional residual benefits for the environment. The assessment quantifies specific benefits to NAS users.

Benefits to the FAA take the form of reduced workload, increased common situational awareness, improved communications, increased ease of use, and improved infrastructure. These types of benefits, however, are difficult to assess and quantify. Therefore, the benefits assessment primarily focused on the quantifiable benefit to users and passengers. These quantitative benefits manifest themselves in reduced ground delay and reduced airborne holding. The following capabilities are expected to provide delay saving benefits:

- Integrated Departure/Arrival Capability (IDAC)

- Flexible Scheduling

- Additional Deployment (ACM and TMA).

TBFM Enhancement 1

The TBFM program is implemented in an incremental way through work package deployments.

The latest TBFM Enhancement 1 will provide two capabilities to the existing TBFM system:

- Expanded Deployment of IDAC (IDAC 2)

- TSAS

IDAC automates the coordination of departures from multiple airports over shared and congested NAS resources via improved decision support capabilities and web-based communications. Traffic managers in the ARTCC coordinate the overall process, which includes monitoring departure and en route demand, initiating IDAC departure procedures, and monitoring the traffic flow. IDAC communicates the allocated departure times from the ARTCC to airports, and the traffic managers or controllers at the airports assign the times to individual flights at their facilities. By reducing the verbal coordination time between ARTCC TMU and tower, IDAC increases the departure flow efficiency through more effective utilization of available space over a departure fix or in the overhead flow.

IDAC was developed under WP2; TBFM Enhancement 1 expands the development of IDAC to five additional centers and additional airports. No additional development of IDAC will be performed as part of TBFM Enhancement 1.

TSAS extends scheduling and metering capabilities into the terminal area and provides metering automation tools to terminal controllers and terminal traffic managers. Those controllers and traffic managers become active participants in time-based metering operations as they work to deliver aircraft accurately to Constraint Satisfaction Points (CSPs) within terminal airspace, to include the runway, in accordance with scheduled times at those points. A higher level of coordination takes place with the overlying center regarding the overall metering operation, potentially reducing terminal controller workload. Through TSAS, terminal controllers are better able to support and enable improved operations, such as RNP-RF, through tools that support the merging of mixed equipage traffic flow (such as merging aircraft flying RNP-RF and non-RNP procedures). Terminal traffic mangers will have improved situation awareness through the use of displays that allow for the monitoring of terminal metering operations, similar to the displays used today by center traffic managers to monitor en route metering operations.

This analysis focuses on the following benefits mechanisms:

- Reduced delay resulting from a reduction in missed slots in the overhead stream

- Reduced flight time and fuel burn resulting from more optimal trajectories from the meter fix to the assigned runway threshold

- Reduced delay resulting from more accurate runway delivery

- Increased safety resulting from fewer amendments.

c. Cost Estimates

TBFM WP2

The AJR-4 Investment Analysis Team (IAT) developed a LCCE for the Preferred Alternative encompassing both F&E and O&M costs. Costs were developed using several different methodologies:

- **Function point analysis:** Used to derive the costs associated with software development. A function point analysis was performed based on the requirements for each capability to determine the appropriate effort involved.

- **Parametric models:** Function point analysis served as inputs into SEER-SEM. Results were used to estimate much of the development required for software, throughout the entire lifecycle.

- **Historical Estimate:** Costs were estimated based on the AJR-4 historical record of costs required to develop new capabilities.

- **Build Up:** A combination of historical costs, vendor quotes, and independent studies to identify configuration and hardware requirements for TBFM architecture.

- **Historical Costs:** used factors and actuals derived from Contractor Reporting formats (EVM data, C/SSR formats), both for TMA as well as analogous efforts (e.g., TFMS).

Costs were inflated using the OMB's latest published inflation rates. In addition, costs were risk adjusted by WBS to reflect uncertainty associated with the estimate. The IAT conducted a risk assessment to identify several areas of the program that have the potential to impact costs, including requirements uncertainty, uncertainty of cost and schedule estimates, human factors risk, and technical dependencies on other programs. To account for estimation uncertainty, the risk team identified low, most likely and high ranges for selected WBS elements. Finally, the SEER-SEM modeling effort included risk ranges which were incorporated into those elements.

TBFM Enhancement 1

The TBFM Enhancement 1 lifecycle encompasses the period from FY15 to FY39, with the program baseline from FY15 to FY22. The FAA standard WBS version 5.1 is utilized to model the costs. Each WBS element within the cost estimate is in Base-year 2014 dollars, time-phased, and inflated using the latest OMB inflation indices to calculate the Then-Year point estimate. Risk analysis was then performed to calculate the High-Confidence Lifecycle Cost.

A variety of estimating methodologies are used to derive point estimates for the TBFM system. The following paragraphs summarize the various techniques and data sources used to estimate the cost elements and calculate the high-confidence lifecycle estimate.

The TBFM Program Office provided FAA and Support contractor staffing level estimates for Program Office activities such as program manage-

ment and system engineering. These include the cost of materials and Contractor/Federal labor required to develop, test, and support the TBFM system. The support contractor labor rate is based on estimates for pay scale levels. Federal salaries are based on the Government Service schedule for estimating purposes and adjusted by the standard benefits factor. Level of effort inputs for Testing and Second Level Engineering activities were provided by persons within the appropriate departments within the FAA's Technical Center. Initial and recurring Telecommunication costs were provided by the FAA Telecommunication Infrastructure (FTI) Program Office. Implementation costs for the system were based on input from Engineering Services and implementation SMEs. A logistics estimate for TBFM Enhancement 1 integration with the Standard Terminal Automation Replacement System (STARS) program was provided by that program office.

It is assumed that the contractor will provide software/hardware maintenance support not only through full deployment of the system, but also for the remainder of the lifecycle. The FAA's Second Level Organization role is that of oversight and support for maintenance of software and associated hardware.

TBFM Enhancement 1 hardware costs are based on historical actuals from TBFM WP2 and the projections for future hardware requirements. Software development costs are estimated using the SEER-SEM (Software Estimation Module). Knowledge bases reflecting the system design and functionality were loaded into the model, and the level of effort and schedule of development were calculated and integrated into the lifecycle cost model.

For lifecycle cost risk, the Program Office identified multiple risks associated with the schedule as well as technical and programmatic areas that could impact costs. For each risk, a triangular risk range was applied to appropriate WBS elements. These ranges were then input into a Monte Carlo simulation with a run of 10,000 iterations using

the identified risk ranges to establish the risk adjusted costs.

d. Return on Investment Estimate

TBFM WP2

As part of the economic analysis, B/C ratio, NPV and payback period were calculated. The analysis was based on risk-adjusted cost and benefit estimates. The B/C ratio and the NPV are calculated using a discount rate based on OMB guidelines, which is 7 percent for user benefits and 2.35 percent for cost avoidance/cost effectiveness.

Table 13 provides a summary of the results of the economic analysis.

Net Present Value (FY10$M)	$101.38
B/C Ratio	2.36
Payback Year	2013

Table 13

TBFM Enhancement 1

Using the results of the benefits analysis and the completed cost estimate, programmatic metrics were calculated to determine the financial returns for TBFM Enhancement 1. The costs and benefits presented in Table 14 are in discounted present value units to facilitate comparison. The business case lifecycle is from FY15 to FY39.

Net Present Value (FY15$M)	$291.0
B/C Ratio	2.84
Payback Year	2026

Table 14

The economic metrics for the individual components of TBFM (IDAC 2 and TSAS) were calculated

using 80th percentile for cost and 20th percentile for benefits. The total TBFM Enhancement 1 metrics were calculated using the FAA Economic Analysis Tool (FEAT), which statistically integrates costs and benefits.

TFDM

a. Program Description

Terminal Flight Data Manager (TFDM) is a NextGen program that improves surface management and efficiency.[15] TFDM supports new services that provide automation to current, manually-intensive operations and replaces critical, outdated systems in the NAS. TFDM shares electronic data among controllers, air traffic managers, aircraft operators, and airports. It enables stakeholders to more efficiently stage arrivals and departures and manage surface traffic flow. Stakeholders will have a shared awareness of flights on the ground and in the air; the ability to exchange data electronically; a constantly updated picture of traffic volume; and more accurate predictive modeling tools to make flights more efficient from gate to gate.

The TFDM system will be deployed to a subset of NAS Air Traffic Control Towers (ATCTs). Other FAA facilities will also have access to the TFDM data, including TRACONS, ARTCCs, and ATCSCC. The TFDM contract was awarded in 2016 to Lockheed Martin, which subsequently merged with Leidos. TFDM capabilities will be implemented incrementally at 89 sites in a phased approach, beginning in 2020 and ending by 2028. TFDM program plans include early implementation of a surface display capability, enhanced flight operator data exchange, and electronic flight strips to selected NAS facilities in advance of TFDM system deployment. The business case lifecycle extends 20 years following the last deployment.

b. Benefit Estimates

The major benefits of TFDM include the following:

[15]This summary is primarily based on Final Business Case for Terminal Flight Data Manager (TFDM), RPT-PMO-02-TFDM-16-001, June 15, 2016.

- Introduces electronic flight strips with electronic flight data (EFD), thereby eliminating the need for paper flight strips. TFDM also integrates electronic data from other automation systems within the tower. This offers the potential to reduce errors created with the printing, marking, distribution, and updating of paper flight strips and other tower data.

- Develops and provides data and user interfaces to existing ATC tools from other FAA domains. This supports an environment of integrated surface, arrival/departure, and traffic flow decision processes to maximize airport throughput and reduce delays.

- Improves data exchange with stakeholders. Provides the timely sharing of accurate operational data with all stakeholders, which provides a collaboration capability to predict and manage demand as well as mitigate constraints.

- Implements a new ATCT suite of capabilities. These tools and interfaces increase operational efficiency and reduce controller workload so that controllers can support increased traffic volumes. These tools also will monitor surface movements and capture surface state changes by displaying changes on EFD displays, e.g., displaying a state change when an aircraft moves from a taxi state to line-up and wait (LUAW) state. Shared Flight Operator flight intent data with these ATCT functions will increase situational awareness and predictability. Surface state movement data will be shared with other domains.

- Establishes infrastructure changes to allow initial airport surface collaboration with other FAA facilities. This lays the foundation for full Airport Surface Collaborative Decision Making among all airport surface stakeholders.

- Establishes interfaces to other TFM programs to exchange TFM data to support collaboration. The ability to exchange information between TFM systems and share the data improves situational awareness and collaborative decision making with all affected stakeholders.

- Provides a situational display shared by multiple Air Traffic Control (ATC) domains. A common situational display will ensure that all domains have the same view of current and projected conditions thereby improving coordination and reducing coordination workload.

The primary benefit mechanisms for TFDM include:

- Departure queue management

- Increased opportunity for flight prioritization

- Increased opportunity to take CFR delay at gate

- Improved off-time compliance related to controller departure times

- Improved runway load balancing

- System consolidation and elimination of paper flight strips

- Reduced incidents/accidents on the surface.

TFDM also has additional benefits that are recognized in this analysis but are not monetized, including:

- Emissions savings

- Controller time savings

- Reduced strip mishandling and ATC miscommunication

- Automated traffic count and delay recording

- Providing data and analysis tools for real-time and post-operational assessment

• Meeting national and international commitments for data sharing

• Enabling future Nextgen initiatives.

TFDM benefits were estimated in terms of cost avoidance, flight efficiency gains, and safety. The flight efficiency benefits refer to delay or fuel savings. The delay savings are valued in terms of ADOC and PVT. Safety benefits are derived from the estimated reductions in Operational Incidents (OIs) that result in certain runway incursions. The reduction in these OIs was quantified but not monetized.

Both the safety and efficiency historical baselines are functions of traffic density. The baselines are combined with traffic projections from the FAA Terminal Area Forecasts (TAF) to develop estimates of benefits for each year. In addition, the timeframe for which each benefit starts to accrue is based on when the specific application is to be operationally certified, as well as on user equipage and the commissioning of the necessary ground equipment.

The analysis was performed on an initial set of 89 airports that were planned to have surface surveillance. The list was vetted by the TFDM Program Office and the Surface Operations Office. The set was then expanded to include all airports with the Electronic Flight Strip Transfer System (EFSTS), which the TFDM program plans to subsume. Configuration A benefits were assessed at 27 larger airports that have surface surveillance (i.e., ASDE-X or ASCC). Configuration B benefits were assessed at the 62 remaining sites that were deemed to have too little traffic to merit Configuration B or that lacked surface surveillance. The final set of 89 airports (27 Configuration A and 62 Configuration B) was down-selected using cost-benefit analysis.

c. Cost Estimates

A full risk-adjusted LCCE was performed for TFDM. The estimate consists of F&E and Operations components. The aggregated costs for TFDM include the costs of Materials, Contractor and FAA Federal Labor. The TFDM team collaborated with the FAA Academy, MIT/Lincoln Labs, and the William J. Hughes Technical Center to develop the cost estimates. The key cost driver is the software development.

d. Return on Investment Estimate

Using the results of the benefit and cost analyses, programmatic metrics were calculated to determine the financial benefits for TFDM. The economic analysis values presented in Table 15 represent a "high-confidence" estimate from underlying distributions of possible cost and benefit outcomes using a Monte Carlo simulation. The economic analysis results are based on a life-cycle period of FY16- FY48.

Net Present Value (FY16$M)	$17.00
B/C Ratio	1.03
Payback Year	2047

Table 15

TFMS/CATM

a. Program Description

Traffic Flow Management (TFM) is the air traffic management element that provides strategic planning and management of air traffic demand to ensure a smooth and efficient traffic flow through all FAA controlled airspace. To support this mission, traffic managers (TM) at the ATCSCC and at local facilities (ARTCCs, TRACONs, and ATCTs) use a combination of automation systems, decision support tools and procedures to monitor, evaluate, and manage air traffic flows throughout all phases of flight. These software-based tools provide for:

• A common situational awareness of the current and forecast conditions of the NAS

- Collaborative planning among major NAS users and managers

- Performance analysis of traffic management operations to identify and resolve, on a near real-time basis, problems within the NAS and areas for future improvement.

Collaborative Air Traffic Management Technologies (CATMT)[16] provides direct mission support to the FAA to provide greater capacity by ensuring efficient flow of air traffic through the NAS. CATMT program activities are directly tied to TFM systems that increase effective capacity and mobility in the NAS, especially during periods of degraded performance caused by severe weather or excessive demand.

CATMT activities consist of completing the development of the legacy TFM infrastructure programs including the National Traffic Management Log (NTML); and of the Collaborative Decision Making (CDM) programs including Flight Schedule Monitor (FSM), Route Management Tool (RMT), and Post Operations Evaluation Tool POET). CATMT also incorporates incrementally developed and integrated decision support capabilities for the modernized TFM System (TFMS).

CATM WP2

CATMT Work Package 2 (WP2) includes a portfolio of enhancements to the TFM system to exploit the benefits of the modernized TFM infrastructure. WP2 provides automation and decision support capabilities that leverage the latest available technology and research, enabling more efficient communication and collaboration with aircraft operators. WP2 also modernizes the TFM remote sites now that the ETMS hub was replaced and relocated under TFM-M. WP2 contains two capability categories, one cross-domain coordi-

nation category, and one infrastructure enhancement category:

Airport Congestion Management (ACM) suite

- Arrival Uncertainty Management (AUM)

Weather integration Suite

- Integration of automated weather forecasted products

- Collaborative Airspace Constraint Resolution (CACR)

Domain Integration part 2

- Airborne Reroute Execution (ABRR).

CATM WP3

CATMT WP3 includes enhancements that continue to provide decision support capabilities that leverage the latest technology and research, and enable more efficient communication and collaboration with aircraft operators. WP3 modernizes the TFM remote sites and associated TMU workstations. WP3 contains one cross-domain coordination category, and one infrastructure enhancement category. WP3 capabilities are:

Domain Integration part 2

- Collaborative Information Exchange (CIX)

Tool Suite Enhancements

- TFM Remote Site Re-Engineering (TRSR).

TFMS Enhancement 4 (TFMS E4, formerly known as CATMT WP4)

TFMS E4 is intended to enhance the capabilities of the existing TFMS, by providing enhancements to the demand prediction capabilities and a Deci-

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[16]This summary is based primarily on Business Case Analysis Report for Traffic Flow Management (TFM) Program, Collaborative Air Traffic Management Technologies (CATMT) Work Package 2 (WP2), signed 8/28/2008; Business Case Analysis Report for Traffic Flow Management (TFM) Program, Collaborative Air Traffic Management Technologies (CATMT) Work Package 3 (WP3), 1/26/2010; and Final Business Case Analysis Report for Traffic Flow Management (TFM) Program, Collaborative Air Traffic Management Technologies (CATMT) Work Package 4 (WP4), 5/18/2017.

sion Support Tool (DST) for managing departures in the presence of convection and high demand.[17]

The specific Operational Improvements (OIs) and Investment Increments (II) which this acquisition supports include:

- Full Collaborative Decision Making

- Continuous Flight Day Evaluation.

TFMS E4 aims to provide Traffic Managers with the information and tools that they need to fulfill the TFM mission more effectively. More specifically, CATMT WP4 includes two capabilities:

1. Improved Demand Prediction capability (IDP) - Traffic Managers will have access to more accurate demand predictions and status information presented in an integrated format.

2. Integrated Departure Route Planning tool (IDRP) - Management of departure flows will be facilitated using new, integrated information displays that provide weather, traffic, and airspace resource information to Traffic Managers and Flight Operators.

b. Benefit Estimates

CATM WP2

The CATMT WP2 BCAR quantifies specific benefits to NAS users, and enumerates qualitative benefits to the FAA, NAS users and society. Table 16 summarizes the benefits types.

CATM WP3

CATMT WP3 builds upon the modernized TFM system, and provides the modernized remote site infrastructure for current and future CATMT capabilities.

CATMT WP3 capabilities provide modernized software infrastructure, automation, and data for display and use in decision support tools to:

- Increase efficient use of existing capacity

- Reduce manual workload

- Increase common situational awareness

- Reduce delay in the terminal and en route airspaces.

Benefit Category	Quantitative	Qualitative
FAA	Cost avoidance and savings	Ensure a viable future More efficient use of NAS resources Workload reduction Common Situational Awareness
NAS Users	ADOC and PVT benefits due to: • Reduced ground delay • Reduced airborne delay.	Users ability to request favored routes and implement their preferred business models and strategies Reduced diversions and cancellations Common Situational Awareness
Society		Environmental

Table 16

[17]CATMT WP4 is now referred to as TFMS Enhancement 4.

Benefits to the FAA take the form of reduced workload, increased common situational awareness, improved communications, increased ease of use, and improved infrastructure. The benefits assessment primarily focused on the quantifiable benefits to the FAA as well as NAS users and passengers. These quantitative benefits manifest themselves in reduced airborne holding and FAA cost avoidance. CATMT WP3 CIX (Collaborative Information Exchange) is expected to provide delay saving benefits, while the TFM Remote Site Re-engineering effort provides FAA cost avoidance. WP3 capabilities provide additional residual benefits for the environmental.

TFMS E4

The benefits for TFMS E4 are delivered by two key capabilities of the program: IDP and IDRP. The benefits analysis for these capabilities was based on 2014 operations, extrapolated to 2020-2032. The extrapolations included accounting for increases in demand using the FAA Terminal Area Forecast Summary for 2013-2040, and for increases in airport capacity using data from FAA Airport Capacity Profiles 2014. This latter source includes capacity increases due to both runway construction and NextGen Operational Improvements.

For cases where demand was projected to grow faster than capacity was added (i.e., demand would exceed capacity), demand growth was limited. This assumes that exponential increases in delay that would otherwise result would not be tolerated. Capping demand to capacity growth likely reduces the overall out-year benefits calculated for each capability.

c. Cost Estimates

CATM WP2

The ATO-R Investment Analysis Team (IAT) developed a lifecycle cost estimate for the Preferred Alterative encompassing both F&E and O&M costs. Costs were primarily developed using a combination of three different methodologies:

- **SLOC Estimate:** Used to derive the costs associated with software development. A function point analysis was performed, based on the requirements for each capability, to determine the effort involved.

- **Historical Estimate:** Costs were estimated based on the historical record of costs required to develop new capabilities, which were used to determine some of the effort associated with software development.

- **WP 1 Cost Estimate:** Due to the similarities of the investment with WP 1, this approach was used to determine costs for a number of WBS elements (e.g., Program Management, Test & Evaluation) under the assumption that the cost of Software Design and Development is the key driver, and that contactor continuity provides validity to these estimates.

Costs were inflated using OMB's latest published inflation rates. In addition, costs were risk adjusted by WBS to reflect any uncertainties associated with the estimate. The IAT conducted a risk assessment to identify several areas of the program that have the potential to impact cost, including: requirements uncertainty, uncertainty of cost and schedule estimates, human factors risk, and technical dependencies on other programs. To account for estimation uncertainty, the risk team identified low, most likely and high ranges for selected WBS elements.

CATM WP3

The Investment Analysis Team (IAT) developed a lifecycle cost estimate for the Preferred Alternative encompassing both F&E and O&M costs. Costs were primarily developed using a combination of three different methodologies:

- **SLOC Estimate:** Used to derive the costs associated with software development. A function point analysis was performed, based on the requirements for each capability, to determine the effort involved.

- **Historical Estimate:** Costs were estimated based on the historical record of costs required to develop new capabilities, which were used to determine some of the effort associated with software development.

- **Hardware and COTS software build-up:** Based on system requirements, hardware and COTS software elements were compiled and costs were estimated using vendor pricing.

Costs were inflated using OMB's latest published inflation rates. In addition, costs were risk adjusted by WBS to reflect any uncertainties associated with the estimate. The IAT conducted a risk assessment to identify several areas of the program that have the potential to impact cost, including: requirements uncertainty, uncertainty of cost and schedule estimates, human factors risk, and technical dependencies on other programs. To account for estimation uncertainty, the risk team identified low, most likely and high ranges for selected WBS elements.

TFMS E4

The LCCE identifies the acquisition and sustainment costs for the new WP4 software functionality. The Facilities and Equipment (F&E) costs for new WP4 capabilities cover the FY 2016 through FY 2022 timeframe and O&M costs cover the period from FY 2016 through FY 2032.

d. Return on Investment Estimate

CATM WP2

As part of the economic analysis, the B/C ratio, NPV, and payback period were calculated based on risk-adjusted cost and benefit estimates. The B/C ratio and the NPV are calculated using a discount rate based on OMB guidelines, which is 7 percent for this analysis.

Table 17 provides a summary economic analysis.

Net Present Value (FY08$M)	$242.5
B/C Ratio	3.41
Payback Year	2015

Table 17

CATM WP3

The B/C ratio and the NPV are calculated using a discount rate based on OMB guidelines and on the interest rates for treasury notes and bonds, which for this analysis is 7 percent for NAS user benefits and 2.7 percent for FAA benefits.

Table 18 provides a summary of the economic analysis.

Net Present Value (FY09$M)	$3.0
B/C Ratio	1.06
Payback Year	2022

Table 18

TFMS E4

Table 19 provides a summary of the economic analysis for TFMS E4.

Net Present Value (FY16$M)	$246.0
B/C Ratio	8.41
Payback Year	2021

Table 19

3.NextGen Priority List

The objective of the NextGen Advisory Committee (NAC) is to provide independent advice and recommendations to the FAA and to respond to specific tasks received directly from the FAA.[18] The advice, recommendations, and responses to FAA-assigned tasks relate to concepts, requirements, operational capabilities, the associated

[18]https://www.faa.gov/nextgen/nac/

use of technology, and related considerations to operations that affect the future of the Air Traffic Management System. In addition, the NAC recommends consensus-driven standards for FAA consideration relating to Air Traffic Management System modernization, which the FAA may adopt.

The FAA, in coordination with the NAC, has developed a prioritization of the NextGen programs that considers the need for a balance between long-term and near-term user benefits with a focus on meeting the NAC's "high benefit, high readiness" criteria.

a. Evolution and Refinement of NextGen Priorities

Since 2009, the FAA and the aviation community have been collaborating on the successful implementation of NextGen in the NAS. A milestone event occurred in July 2013 when the FAA requested the NAC to develop recommendations related to the Agency's NextGen investments.[19] In light of budget pressures and possible sequestration impacts, the NAC was requested to review current FAA plans and activities and develop a prioritized list of Tier 1 (consensus on activities that should continue no matter what) and Tier 2 (consensus on activities that should continue, resources permitting) recommendations. The NAC followed a process that incorporated an analytic, transparent, repeatable, defensible approach to prioritizing NextGen capabilities and related activities. This approach entailed applying a ranked list of weighted criteria against a candidate list of capabilities and activities. After applying these rankings against a list of 36 NextGen capabilities, the result was an outcome consistent with previous NAC recommendations.

Subsequently, the FAA formalized the collaboration process by publishing the Joint Implementation Plan. The joint plan focuses on delivering tangible implementation benefits across all NextGen focus areas, and aligns the agency's and the aviation community's priorities.

The FAA presented the original plan to the U.S. Congress in 2014. The plan included the collaborative work between the FAA and NAC industry stakeholders to commit to milestones across four focus areas: Multiple Runway Operations, Performance Based Navigation, Surface and Data Sharing, and Data Comm, which were all codified in the original plan. Work began on a fifth focus area, the NEC, in February 2017. Later that year in October, the initial industry recommendations to implement activities over an 18-month period were presented.

In June 2017, the NAC was tasked by the FAA and presented another set of recommendations to include in the NextGen Advisory Committee NextGen Priorities Joint Implementation Plan CY2018-2021, advancing the time period out to 2021.

The result of this government-industry collaboration is a plan that captures FAA implementation, pre-implementation, and industry milestones. The FAA and aviation community are committed to reporting regularly to track the completion of the milestones, identify risks and mitigations, and analyze benefits.

The history of collaboration between the FAA and the aviation community to prioritize NextGen investments is captured in the following documents:

- NextGen Prioritization, approved by the NextGen Advisory Committee, September 2013

- NextGen Priorities Joint Implementation Plan (2014)[20]

- NextGen Priorities October 2015 Joint Implementation Plan, Revision 1[21]

[19]Letter from Michael P. Huerta (FAA Administrator) to Margaret Jenny (RTCA President) dated July 12, 2013.
[20]https://www.faa.gov/about/office_org/headquarters_offices/ang/nac/media/ng_priorities.pdf
[21]https://www.faa.gov/about/office_org/headquarters_offices/ang/nac/media/NGPriorities-2015.pdf

- NextGen Joint Implementation Plan 2016[22]

- NextGen Priorities Joint Implementation Plan, Rolling Plan 2017-2019[23]

- NextGen Priorities October 2017 Joint Implementation Plan Update Including the Northeast Corridor[24]

- NextGen Advisory Committee, NextGen Priorities Joint Implementation Plan CY2019-2021.[25]

b. Current NextGen Priorities

The NAC NextGen Priorities Joint Implementation Plan CY2019-2021[26], published in June 2019, contains milestones agreed to by FAA and industry, for implementation through 2021, in four focus areas: Multiple Runway Operations, Performance Based Navigation, Surface and Data Sharing, and Data Communications. The Northeast Corridor (NEC), the busy airspace between Washington, D.C., and Boston that includes Philadelphia, New York City, and associated airspace, is also included in the plan as an additional NextGen Priority area, ensuring enhanced operations in the most congested airspace in the NAS.

The FAA and industry have identified commitments within each of the focus areas and the Northeast Corridor to increase safety; reduce aviation's impact on the environment; enhance controller productivity; and increase predictability, airspace capacity, and efficiency. The FAA and industry will continue to monitor joint progress and be agile and flexible, making adjustments to commitments as necessary.

Focus Area: Multiple Runway Operations

The efficiency of parallel runways, particularly those that are closely spaced, has been limited by the interplay of wake vortices with nearby aircraft. New technology in the cockpit, and due diligence in examining safety standards for closely spaced parallel runway operations (CSPO), have enabled the FAA to advance its procedures and tools to improve runway capacity in all weather conditions. Multiple Runway Operations (MRO) capabilities improve access to these runways and can increase basic runway capacity and throughput by reducing separation between aircraft based on improved wake categorization standards through Consolidated Wake Turbulence (CWT). Improved access will enable more arrivals and/or departures during instrument meteorological conditions, which will increase efficiency and reduce flight delays. These commitments are a subset of the overall series of programs and activities that the FAA has planned to address.

Focus Area: Performance Based Navigation

The FAA is moving to a performance based navigation (PBN) NAS and has published the NAC-endorsed PBN NAS Navigation Strategy.[27] With PBN, the FAA delivers new routes and procedures that primarily use satellite-based navigation and on-board aircraft equipment to navigate with greater precision and accuracy. PBN provides a basis for designing and implementing automated flight paths and redesigning airspace near obstacles for increased access. Benefits include shorter and more direct flight paths, improved airport arrival rates, enhanced controller productivity, increased safety due to repeatable and predictable flight paths, fuel savings, and a reduction in aviation's environmental impact. These commitments

[22] https://www.faa.gov/nextgen/media/NextGen_Implementation_Plan-2016.pdf
[23] https://www.faa.gov/about/office_org/headquarters_offices/ang/nac/media/NG_Priorities_Joint_Implementation_Plan.pdf
[24] https://www.faa.gov/about/office_org/headquarters_offices/ang/nac/media/NGPriorities-2017.pdf
[25] https://www.faa.gov/about/office_org/headquarters_offices/ang/nac/media/NACNextGenPrioritiesJointImplementationPlanCY2019-2021.pdf
[26] https://www.faa.gov/about/office_org/headquarters_offices/ang/nac/media/NACNextGenPrioritiesJointImplementationPlanCY2019-2021.pdf
[27] https://www.faa.gov/nextgen/media/pbn_nas_nav.pdf

are a subset of the overall series of PBN activities the FAA is planning to implement.

The FAA has established a network of thousands of precisely defined PBN routes and procedures to improve air traffic flow efficiency to and from airports throughout all phases of flight. A PBN-centric NAS harmonized with Time Based Management (TBM) will enable Trajectory Based Operations (TBO) in the future. TBO is an air traffic management method for strategically planning, managing, and optimizing flights throughout the operation by using TBM, information exchange between air and ground systems and an aircraft's ability to fly precise paths in time and space through PBN.

Focus Area: Surface Operations and Data Sharing

Some of the greatest efficiencies can be gained while an aircraft is still on the ground and at the gate, and when connecting the surface to the en route airspace. The FAA commits to implementing near-term surface improvements, sharing more data with stakeholders, and completing feasibility assessments of some other capabilities of interest. The goal of these enhancements is to measurably increase predictability and surface efficiency. These commitments are a subset of the overall series of programs and activities the FAA is planning to improve operations in these domains.

The NAC developed a set of commitments for surface and data sharing including Terminal Flight Data Manager (TFDM), a tower-based system that improves surface management and efficiency. TFDM supports new services that automate current manually-intensive operations and replaces outdated systems in the tower. The introduction of TFDM into the NAS is a key building block for the FAA's TBO concept.

The remaining commitments involve Airspace Technology Demonstration 2 (ATD-2), the Integrated Arrival/Departure/Surface (IADS) field demonstration at Charlotte Douglas International Airport (CLT). This initiative was launched

in collaboration with NASA in September 2017. ATD-2 capabilities will help the FAA increase NAS benefits for TFDM, and aid with implementation of TBO. The FAA's goal of establishing TBO in the NAS is to maximize airspace capacity and efficiency with more sophisticated and seamlessly integrated information about the future position of aircraft, while maintaining safety and minimizing environmental impacts.

Focus Area: Data Communications

The Data Communications (Data Comm) program will provide digital communications services between pilots and air traffic controllers as well as enhanced air traffic control information to airline operations centers. Data Comm will provide a direct link between ground automation and flight deck avionics for safety-of-flight clearances, instructions, traffic flow management, flight crew requests and reports.

Data Comm technology is critical to the success of NextGen, enabling efficiencies in both technology and human factors not possible with the current voice system. These services will enhance safety by reducing communication errors, increase controller productivity by reducing communication time between controllers and pilots, and increase airspace capacity and efficiency while reducing delays, fuel burn and carbon emissions.

Focus Area: Northeast Corridor

The Northeast Corridor (NEC) is defined as the airspace that spans from Washington, D.C. to Boston, including Philadelphia and the New York area. The NEC contains the most congested airports and airspace in the United States, and has a significant effect on the daily operations of the NAS. Nearly 50 percent of aviation delays in the NAS are attributable to the Northeast Corridor. Given the complex and compact nature of NEC operations, and its connection to the rest of the NAS, single operational improvements can have significant savings in time, particularly during weather events. These enhancements establish a foundation and framework for longer-term imple-

mentation of NextGen using time-based management techniques and precise, repeatable PBN procedures for a more predictable and efficient operation.

Applying TBO capabilities in the NEC is a key part of the FAA's implementation strategy for TBO. TBO is expected to result in more efficient use of system capacity by maximizing airspace and airport throughput, improving operational predictability through more accurate gate-to-gate strategic planning, enhancing flight efficiency through integrated operations, and increasing operational flexibility through increased user collaboration regarding trajectories and priorities.

The recommended implementations for the NEC are designed to address key issues that negatively impact operational performance today. This includes mitigations that address adverse weather, a major issue in the NEC. Each implementation includes both FAA and industry commitments. Because of interdependencies among the NEC initiatives, and the associated impact on the national aviation system, it is important to continually assess and address, as needed, to ensure that system improvements are occurring and dependent milestones are being met. Some primary themes for the NEC recommendations are deconflicting arrivals into the New York area, improving arrival and departure throughput, easing congestion points, and addressing community noise.

4. Conclusions

In response to Section 503 of H.R. 302, the FAA Reauthorization Act of 2018, this report has documented the ROI of each major acquisition program within the NextGen Facilities and Equipment budget:

- ADS-B (Automatic Dependent Surveillance – Broadcast), which includes Surveillance Broadcast Services (SBS) Future Segments

- AIMM (Aeronautical Information Management Modernization) Segment 2 (S2)

- CSS-Wx (Common Support Services – Weather)

- Data Comm (Data Communications) Segment 1 Phase 1 (S1P1) and Segment 1 Phase 2 (S1P2)

- ERAM (En Route Automation Modernization) Enhancements 2 (EE2)

- NWP (NextGen Weather Processor)

- SWIM (System Wide Information Management) Segments 1, 2A, and 2B

- TBFM (Time Based Flow Management) Work Package 2 (WP2) and Enhancement 1

- TFDM (Terminal Flight Data Manager)

- TFMS (Traffic Flow Management System) / Collaborative Air Traffic Management Technologies (CATMT) Work Package 2 (WP2), Work Package 3 (WP3), and Enhancement 4 (E4)

With the exception of EE2, each of these programs, as baselined, indicated a positive return on investment. EE2 increases the safety and efficiency of ERAM's operational services; these capabilities were requested by ERAM users and our international ANSP partners, and are primarily infrastructure enhancements for which benefits were not monetized.

This report also summarizes the most recent NextGen priority list that reflects the need for a balance between long-term and near-term user benefits. The current priorities consist of five focus areas:

- Multiple Runway Operations

- Performance Based Navigation

- Surface and Data Sharing

- Data Communications

- Northeast Corridor

The FAA and industry have identified commitments within each of the focus areas to increase safety; reduce aviation's impact on the environment; enhance controller productivity; and increase predictability, airspace capacity, and efficiency.

APPENDIX C:

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

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ACRONYMS, INITIALISMS, AND ABBREVIATIONS

4-D
Four-Dimensional

ABRR
Airborne Reroutes

ACM
Airport Congestion Management

ACS
Aeronautical Common Services

ADOC
Aircraft Direct Operating Cost

ADS-B
Automatic Dependent Surveillance–Broadcast

ADS-C
Automatic Dependent Surveillance–Contract

ADS-R
Automatic Dependent Surveillance–Rebroadcast

AEFS
Advanced Electronic Flight Strips

AHA
Aircraft Hazard Area

AI
Aeronautical Information

AIDA
Aeronautical Information Data Analytics

AII
Aeronautical Information Integration

AIMM
Aeronautical Information Management Modernization

AIQS
Aeronautical Information Query and Subscription Service

AISS
Aeronautical Information Subscription Service

AIX
Advanced Interactive eXecutive, a Unix operating system developed by IBM

AJM-2
An office in the FAA Air Traffic Organization Program Management Organization

AJR-4
An office in the FAA Air Traffic Organization System Operations Services

AMS
Acquisition Management System

ANSP
Air Navigation Service Provider

AOC
Airline Operations Center

APO
FAA Office of Aviation Policy and Plans

ARC
Aviation Rulemaking Committee

ARTCC
Air Route Traffic Control Center

ASDE-X
Airport Surface Detection Equipment, Model X

ASEPS
Advanced Surveillance Enhanced Procedural Separation

ASIAS
Aviation Safety Information Analysis and Sharing

ASPM
Aviation System Performance Metrics

ASSC
Airport Surface Surveillance Capability

AT
Air Traffic

ATC
Air Traffic Control

ATCSCC
Air Traffic Control System Command Center

ATCT
Air Traffic Control Tower

ATD-2
Airspace Technology Demonstration 2

ATM
Air Traffic Management

ATOP
Advanced Technologies and Oceanic Procedures

AUM
Arrival Uncertainty Management

B/C
Benefit/Cost

BCAR
Business Case Analysis Report

BOE
Basis of Estimate

BSFS
Baseline Services Future Segments

BY
Base Year

C/SSR
Cost/Schedule Status Report

CACR
Collaborative Airspace Constraint Resolution

CATM
Collaborative Air Traffic Management

CATMT
Collaborative Air Traffic Management Technologies

CAVS
Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation

CDF
Cumulative Probability Distribution

CDM
Collaborative Decision-Making

CFR
Call for Release

CIWS
Corridor Integrated Weather System

CIX
Collaborative Information Exchange

CLEEN
Continuous Lower Energy, Emissions, and Noise

CLIN
Contract Line Item Number

COE
Center of Excellence

CONOPS
Concept of Operations

CONUS
Continental United States

COTS
Commercial off-the-Shelf

CPDLC
Controller Pilot Data Link Communications

CRDA
Converging Runway Display Aid

CSIT
Collaborative Site Implementation Team

CSPO
Closely Spaced Parallel Operations

CSPR
Closely Spaced Parallel Runways

CSS-Wx
Common Support Services–Weather

CWAF
Convective Weather Avoidance Field

CWAM
Convective Weather Avoidance Model

CWBS
Contract Work Breakdown Structure

CWT
Consolidated Wake Turbulence

CY
Calendar Year

Data Comm
Data Communications

DCIS
Data Communications Integrated Services

DCL
Departure Clearance

DCNS
Data Communications Network Service

DME
Distance Measuring Equipment

DOD
Department of Defense

DOT
Department of Transportation

DS
Display System

DSP
Departure Spacing Program

DSS
Decision Support System

DST
Decision Support Tool

E4
Enhancement 4

EA
Enterprise Architecture

ECG
En Route Communications Gateway

EDC
En Route Departure Capability

EE1, EE2
En Route Automation Modernization (ERAM) Enhancement 1, ERAM Enhancement 2

EFD
Electronic Flight Data

EFSTS
Electronic Flight Strip Transfer System

EFVS
Enhanced Flight Vision System

EIIA
Economic Information for Investment Analysis

ELA
Enterprise License Agreement

ELMS
FAA Electronic Learning Management System

ELSO
Equivalent Lateral Spacing Operations

ELVO
Expanded Low Visibility Operations

EMS
Environmental Management Systems

EoR
Established on Required Navigation Performance

ERAM
En Route Automation Modernization

ERIDS
En Route Information Display System

ES
Engineering Services

ES2
En Route Automation Modernization Sustainment 2

ESM
Enterprise Service Monitoring

ETM
Upper Class E Traffic Management

ETMS
Enhanced Traffic Management System

EUROCONTROL
European Organization for the Safety of Air Navigation

EVM
Earned Value Management

EXPWY VIS
Expressway Visual Approach for LaGuardia Airport

F&E
Facilities and Equipment

FAA
Federal Aviation Administration

FAAAC
FAA Mike Monroney Aeronautical Center

FANS
Future Air Navigation System

FCS
FAA Cloud Services

FEAT
FAA Economic Analysis Tool

FedEx
Federal Express

FID
Final Investment Decision

FIM
Flight Deck Interval Management

FIS-B
Flight Information Service–Broadcast

FOC
Flight Operations Center

FSM
Flight Schedule Monitor

FSS
Flight Service Station

FTE
Full Time Equivalent

FTI
FAA Telecommunications Infrastructure

FY
Fiscal Year

GBAS
Ground Based Augmentation System

GIM-S
Ground-based Interval Management–Spacing

GLDMN
Area Navigation departure procedure for LaGuardia Airport

HCLCC
High Confidence Lifecycle Cost

HPE
Hewlett Packard Enterprise

HQ
Headquarters

HUR
High Update Rate

IADS
Integrated Arrival/Departure/Surface

IAM
Identity and Access Management

IAT
Investment Analysis Team

ICAO
International Civil Aviation Organization

IDAC
Integrated Departure/Arrival Capability

IDP
Improved Demand Prediction Capability

IDRP
Integrated Departure Route Planning

IFCET
Inter-Facility Communications Engineering Team

IFR
Instrument Flight Rules

IGCE
Independent Government Cost Estimate

II
Investment Increment

IID
Initial Investment Decision

ILS
Instrument Landing System

IOC
Initial Operating Capability

IP&A
FAA Office of Investment Planning and Analysis

ISD
In-Service Decision

ISPD
Implementation Strategy and Planning Document

iTBO
Initial Trajectory Based Operations

ITP
In-Trail Procedures

ITWS
Integrated Terminal Weather System

JAT
Joint Analysis Team

JPDO
Joint Planning and Development Office

JRC
Joint Resources Council

JSpOG
Joint Space Operations Group

KVM
Keyboard Video Monitor or, alternatively, Keyboard/Video/Mouse

LCCE
Lifecycle Cost Estimate

LUAW
Line-Up and Wait

MARS
Multiple Airport Route Separation

MCL
Minimum Capabilities List

MIT
Miles-In-Trail

MOPS
Minimum Operational Performance Standards

MRS
Minimum Radar Separation

NAC
NextGen Advisory Committee

NAS
National Airspace System

NAS EA
National Airspace System Enterprise Architecture

NASA
National Aeronautics and Space Administration

NASR
National Airspace System Resource System

NBAA
National Business Aviation Association

NCEI
National Centers for Environmental Information

NCR
National Airspace System Common Reference

NEC
Northeast Corridor

NEMS
National Airspace System (NAS) Enterprise Messaging System or NAS Enterprise Messaging Service

NextGen
Next Generation Air Transportation System

NGIP
NextGen Implementation Plan

NMAC
Near Midair Collision

NNEW
NextGen Network Enabled Weather

NOAA
National Oceanic and Atmospheric Administration

NOTAM
Notice to Airmen

NPV
Net Present Value

NSDA
National Single Data Authority

NSG
Navigation Service Group

NSIP
National Airspace System Segment Implementation Plan

NTHNS
Area Navigation departure procedure for LaGuardia Airport

NTML
National Traffic Management Log

NTSB
National Transportation Safety Board

NWP
NextGen Weather Processor

O&M
Operations and Maintenance

O&S
Operations and Support

ORD
Operational Readiness Decision

OEM
Original Equipment Manufacturer

OGC
Open Geospatial Consortium

OI
Operational Improvement or Operational Incident

OMB
Office of Management and Budget

OPD
Optimized Profile Descent

OS
Operating System

OSS
One Stop Shop

PANYNJ
Port Authority of New York and New Jersey

PBN
Performance Based Navigation

PC/RISC
Personal Computer/Reduced Instruction Set Computer

PDRR
Pre-Departure Reroute

PGW
Protocol Gateway

PMO
Program Management Office

PO
Program Office

POET
Post Operations Evaluation Tool

PTR
Problem Trouble Report

PV
Present Value

PVT
Passenger Value of Time

RF
Radius-to-Fix

RFP
Request for Proposal

RIO
Risk, Issues, and Opportunities

RMT
Route Management Tool

RNAV
Area Navigation

RNP
Required Navigation Performance

ROI
Return on Investment

RTA
Required Time of Arrival

RVR
Runway Visual Range

RVSM
Reduced Vertical Separation Minima

RW
Runway

S1 or S2
Segment 1 or Segment 2

SAA
Special Activity Airspace

SAPT
Service Availability Prediction Tool

SBS
Surveillance and Broadcast Services

SCDS
System Wide Information Management Cloud Distribution Service

SDI
Space Data Integrator

SE&TR
System Enhancements and Technical Refresh

SEPM
Systems Engineering and Program Management

SESAR
Single European Sky Air Traffic Management Research

SEER-SEM
Software Evaluation and Estimation of Resources - Software Estimating Model

SETR
System Enhancements and Technical Refresh

SID
Standard Instrument Departure

SLE
Second Level Engineering

SLOC
Source Lines of Code

SME
Subject Matter Expert

SOA
Service Oriented Architecture

SOW
Statement of Work

STAR
Standard Terminal Arrival

STARS
Standard Terminal Automation Replacement System

STDDS
System Wide Information Management Terminal Data Distribution System

SVGS
Synthetic Vision Guidance Systems

SVT
Surface Visualization Tool

SWAC
System Wide Analysis Capability

SWIFT
System Wide Information Management (SWIM) Industry-FAA Team

SWIM
System Wide Information Management

S1P1, S1P2
Segment 1 Phase 1, Segment 1 Phase 2

S2
Segment 2

TAF
Terminal Area Forecast

TBFM
Time Based Flow Management

TBM
Time-Based Metering

TBO
Trajectory Based Operations

TDLS
Tower Data Link Services

Tech Ops
Technical Operations

TF
Track-to-Fix

TFDM
Terminal Flight Data Manager

TFM
Traffic Flow Management

TFMS
Traffic Flow Management System

TFR
Temporary Flight Restriction

TIBCO
A U.S.-based software development company

TIS-B
Traffic Information Service–Broadcast

TM
Traffic Managers

TMA
Traffic Management Advisor

TMI
Traffic Management Initiative

TMU
Traffic Management Unit

TOS
Trajectory Options Set

TRACON
Terminal Radar Approach Control

TRSR
Traffic Flow Management Remote Site Reengineering

TSAS
Terminal Sequencing and Spacing

TTS
Test and Training System

TY
Then Year

UAM
Urban Air Mobility

UAS
Unmanned Aircraft Systems

UHD
Ultra High Definition

UPP
Unmanned Aircraft Systems Traffic Management System Pilot Program

US
United States

USS
Unmanned Aircraft Systems Service Supplier

UTM
Unmanned Aircraft Systems Traffic Management System

VDL
Very High Frequency Data Link

VDL-2
Very High Frequency Data Link–Mode 2

VHF
Very High Frequency

VNAV
Vertical Navigation

VOR
Very High Frequency Omnidirectional Range

Wake Recat
Wake Recategorization

WARP
Weather and Radar Processor

WBS
Work Breakdown Structure

WCS
Web Coverage Service

WFS
Web Feature Service

WJHTC
William J. Hughes Technical Center

WMS
Web Map Service

WMSCR
Weather Message Switching Center Replacement

WP2, WP3
Work Package 2, Work Package 3

XML
Extensible Markup Language

Core Airports

The Core Airports are those that have the most significant impact on the operation of the NAS.

ATL	Hartsfield-Jackson Atlanta International Airport
BOS	General Edward Lawrence Logan International Airport (Boston)
BWI	Baltimore-Washington International Thurgood Marshall Airport
CLT	Charlotte Douglas International Airport
DCA	Ronald Reagan Washington National Airport
DEN	Denver International Airport
DFW	Dallas/Fort Worth International Airport
DTW	Detroit Metropolitan Wayne County Airport
EWR	Newark Liberty International Airport
FLL	Fort Lauderdale-Hollywood International Airport
HNL	Daniel K. Inouye International Airport (Honolulu)
IAD	Washington Dulles International Airport
IAH	George Bush Intercontinental Airport (Houston)
JFK	John F. Kennedy International Airport (New York)
LAS	McCarran International Airport (Las Vegas)
LAX	Los Angeles International Airport
LGA	LaGuardia Airport (New York)
MCO	Orlando International Airport
MDW	Chicago Midway International Airport
MEM	Memphis International Airport
MIA	Miami International Airport
MSP	Minneapolis-Saint Paul International/Wold-Chamberlain Airport
ORD	O'Hare International Airport (Chicago)
PHL	Philadelphia International Airport
PHX	Phoenix Sky Harbor International Airport
SAN	San Diego International Airport
SEA	Seattle-Tacoma International Airport
SFO	San Francisco International Airport
SLC	Salt Lake City International Airport
TPA	Tampa International Airport

Other Airports and Facilities Referenced in this Report

CLE   Cleveland Hopkins International Airport

CVG   Cincinnati/Northern Kentucky International Airport

DAL   Dallas Love Field Airport

FNL   Northern Colorado Regional Airport

IND   Indianapolis International Airport

JYO   Leesburg Executive Airport

PIT   Pittsburgh International Airport

SDF   Louisville Muhammad Ali International Airport

TEB   Teterboro Airport

ZBW   Boston Air Route Traffic Control Center

ZDC   Washington Air Route Traffic Control Center

ZNY   New York Air Route Traffic Control Center

U.S. Department of Transportation
Federal Aviation Administration