UPDATE

to The Business Case for the Next Generation Air Transportation System based on the Future of the NAS Report

JULY 2016

July 2016

I am pleased to provide you with an update to *The Business Case for NextGen*. This document provides an estimate of the high-level economic value of the Next Generation Air Transportation System (NextGen) and is fully aligned with our updated plans outlined in *The Future of the NAS* report.

The FAA and its partners continue to make significant progress in the modernization of our air traffic infrastructure and transformation of our operation. NextGen improvements in every phase of flight are resulting in more and more benefits to airlines, passengers, the FAA and other users.

We estimate that implemented changes already have accrued $1.6 billion of benefits since 2010. We expect that by 2030, the total benefits of NextGen improvements will be $160.6 billion, at a cost of $35.8 billion to the FAA and the aviation industry. After discounting to present value, the benefit-to-cost ratio is 3-to-1. More details are in this document and its appendices.

This report provides the only NAS-wide analysis of benefits and costs of NextGen improvements by combining data from a number of sources, including system-wide modeling, business cases for individual programs, and observed results. To ensure that cost and benefit estimates are current, we analyze them regularly using the most up-to-date values that consider the progressive maturity of the various NextGen programs. *The Business Case* is consistent with assumptions about investments, benefits and costs in *The Future of the NAS*, and the two will be updated concurrently as needed. Several other changing factors that influence the economic analyses of NextGen will continue to be tracked internally by the FAA including program plans, forecasts of future fleet and air traffic, current values for fuel and other airline operating costs, current values for passenger time, and improvements to the FAA's system-wide analysis capability.

We are excited about the potential that NextGen has already begun to prove in delivering greater efficiency, predictability and resiliency for airspace users. NextGen improvements in technology and procedures represent a widespread, transformative change in the management and operation of the way we fly. The aerospace sector is a vital element in the country's economy. Aviation contributes $1.5 trillion to the U.S. economy, generates more than 11.8 million jobs with earnings of nearly $460 billion and makes up 5.4 percent of our gross domestic product. Continued support for NextGen is essential as we forge the next generation of flight and maintain aviation's vitality in the 21st century.

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INTRODUCTION

This report presents the Federal Aviation Administration's (FAA) Business Case for the Next Generation Air Transportation System (NextGen). NextGen is a wide-ranging series of improvements that will transform the air transportation system, encompassing new air traffic management technologies and procedures; airport infrastructure improvements; and environmental, safety and security-related enhancements. This Business Case considers only the air traffic management aspects of NextGen, as the costs of these improvements are most directly borne by the FAA and system users.

Specifically, this Business Case focuses on the improvements described in the Future of the National Airspace System (NAS) report[1] and in the 2015 NextGen Implementation Plan[2]. Work for NextGen improvements began in 2007. By 2009, work had spread across multiple programs, which constitute NextGen's foundations. Consequently, as of 2015, work on NextGen improvements is widespread, far-reaching and at a variety of maturity levels. Some early improvements have been deployed and are currently yielding benefits. Of the future improvements, some have received investment decisions, which provide dedicated funding, detailed work plans and deployment schedules. Other future improvements are still under internal FAA concept development, review and investment analysis. For the first time, the Business Case for NextGen breaks out its cost and benefit estimates by improvement maturity level, including sunk costs and benefits already reaped. This was done in order to associate the costs and benefits of improvements with their deployment status and schedule certainty.

In addition to these changes, this year's report revises 2014 estimates of the costs and benefits of NextGen. Revisions include updated traffic and fleet forecasts, updated economic factors, improvements to the fast-time model used to estimate most of the operational benefits, changes to planned deployment dates for various improvements and changes to specific business plans that were incorporated into this analysis. Lastly, a new model was used to estimate the equipage level and associated costs borne by aircraft operators to use NextGen improvements.

Unless otherwise noted, all financial values are given in 2015 dollars. Also, component values may not exactly sum to their reported totals due to rounding.

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[1] Federal Aviation Administration, *Future of the National Airspace System (NAS)*, Version (2016), faa.gov/nextgen/media/FutureOfTheNAS.pdf.

[2] Federal Aviation Administration, *NextGen Implementation Plan* (2015), available at faa.gov/NextGen/library

SCOPE OF ANALYSIS

WHAT IS INCLUDED IN THIS BUSINESS CASE

This Business Case deals only with improvements resulting directly from NextGen. These improvements, typically either large capital projects or new aircraft procedures, impact the NAS. Capital improvements include programs that use new technologies to improve efficiency. As an example, Data Communications (Data Comm) augments voice communications between a controller and aircraft with a secured text messaging system. Multiple communications per flight that are repeated on tens of thousands of flights daily means that the cumulative time savings from Data Comm can result in fewer delays and more consistent performance in the NAS.

Additionally, new or revised aircraft procedures are being built based on the application of new technologies. Relieving these outdated technological limitations from new flight procedures could increase the overall performance of the NAS, including more fuel-efficient trajectories. Metroplex Airspace Redesign is an example of overhauling aircraft procedures in congested airspaces over large cities by using Performance Based Navigation (PBN) technologies.

The NextGen capital programs included within this Business Case are:

- Automatic Dependent Surveillance–Broadcast (ADS-B)
- Collaborative Air Traffic Management (CATM)
- Data Communications (Data Comm)
- Time Based Flow Management (TBFM)
- System Wide Information Management (SWIM)
- NextGen Weather Processor (NWP)
- Terminal Flight Data Manager (TFDM)

The NextGen procedural improvements included within this Business Case are:

- Performance Based Navigation
- Metroplex Airspace Redesign (Metroplex)
- Wake Recategorization (Wake Recat)
- Improved Multiple Runway Operations (IMRO)

Note that not all anticipated benefits of these programs have been captured in this Business Case. In some cases, modeling limitations or a lack of data have restricted the ability to estimate benefits for some operational capabilities or locations.

This cost-benefit analysis is based on the funding schedule specified in the FAA’s Capital Investment Plan (CIP), submitted in conjunction with the president’s Fiscal Year 2016 budget. The projects that are in that CIP are included in this analysis.

A more detailed explanation of the CIP is available in Appendix B, Cost Methodology.

Unlike previous presentations of the Business Case for NextGen, this report not only looks ahead to the costs and benefits of future plans but also reviews improvements already deployed.

WHAT IS EXCLUDED IN THIS BUSINESS CASE

Though NextGen is a wide-ranging suite of technologies, they alone do not address all issues facing the NAS. Investments are also being made by government agencies and other stakeholders in other domains that directly affect air transportation. Examples of what are excluded in the Business Case are:

- Airport infrastructure projects
- Security benefits
- Fuel efficiency benefits of airframe and engine improvements
- Environmental effects other than CO_2
- Emission benefits of synthetic fuels
- Unmanned Aircraft Systems and commercial space operations
- FAA staffing profiles

BENEFITS OF NEXTGEN

NextGen's progress is made through improvements, the implementation of which benefits aircraft operators, passengers, the government and society at large. The capital and procedural improvements highlighted in the section above generally lead to increased NAS capacity, improved flight efficiency, increased safety and improved capital productivity. The benefits that are then monetized include:

- Internal FAA cost savings
- Reduced passenger travel time
- Decreased aircraft operating costs
- Decreased fuel consumption
- Fewer and shorter travel delays
- Avoided cancellations
- Additional flights
- Reduced carbon dioxide emissions
- Reduced injuries, fatalities and aircraft losses and damages

To provide the reader with more information on benefits with differing levels of maturity, NextGen improvements are divided into three types: implemented, baselined and anticipated. Implemented improvements are fully or partially deployed. Deployment at additional locations primarily comprises the remaining work for which funding has been internally approved. Future improvements are divided into baselined and anticipated improvements. Baselined improvements include those capital investment programs that have FAA-approved business plans and funding. Development work is underway, but deployment has not begun. Baselined improvements also include investments in near-term procedure development that might not go through the FAA's formal acquisition management process.[3] Anticipated improvements are still in the planning phase and preliminary work is being conducted to create business plans. Funding for development has not been approved.

Of NextGen's projected $160.6 billion in benefits, implemented improvements account for $13.2 billion — $1.6 billion of which have already been delivered. Baselined improvements and anticipated improvements account for $65.1 billion and $82.2 billion, respectively. The next three subsections discuss the three types of improvements in detail. The realized and expected benefits from the improvements are given in Table 1 and Figure 1.

Table 1 - Summary of NextGen Benefits

Billions, 2015 $	Benefits to Date (2010–2014)	Future Benefits (2015–2030)	**Total Benefits (2010–2030)**
Implemented Improvements	$1.6	$11.7	**$13.3**
Baselined Improvements	N/A	$65.1	**$65.1**
Anticipated Improvements	N/A	$82.2	**$82.2**
All Improvements	**$1.6**	**$159.0**	**$160.6**

[3] In FAA parlance, a "baselined" capital investment program has gone through the Acquisition Management System and successfully achieved a Final Investment Decision from the Joint Resources Council. Its cost, schedule and performance expectations are documented in an approved "baseline." The term is used more generally here to include other near-term initiatives.

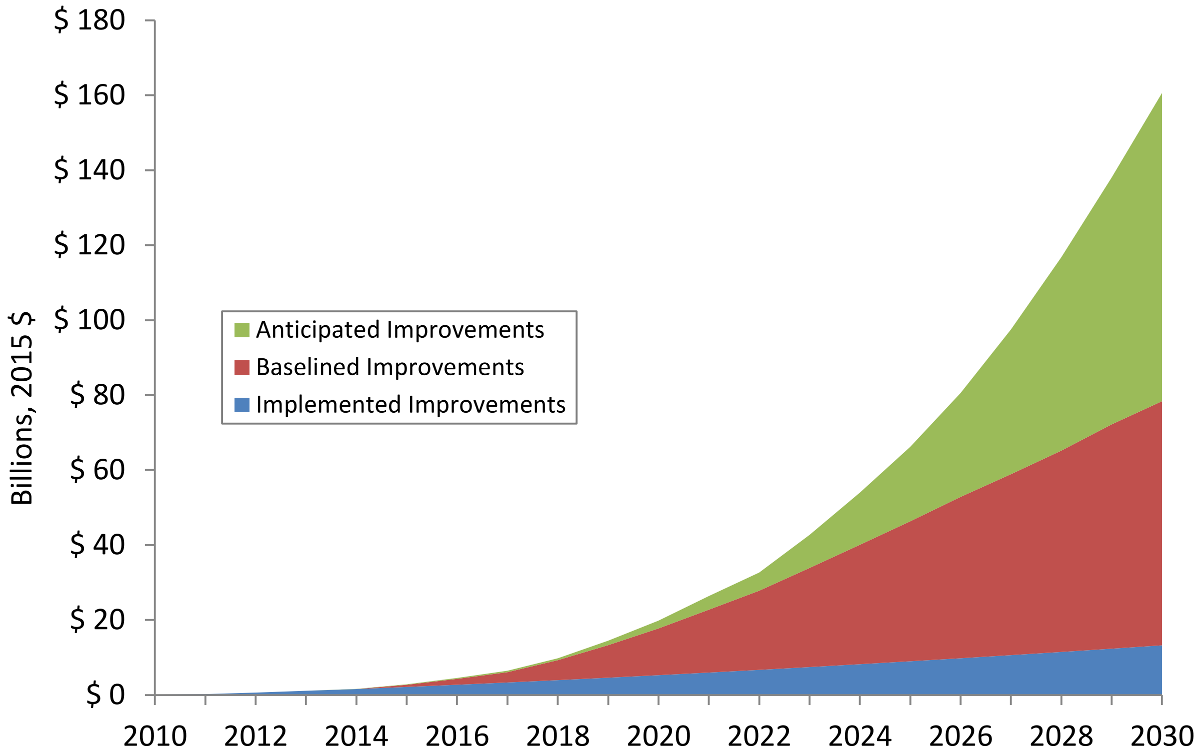

Figure 1 - Projected Benefits of NextGen Improvements

IMPLEMENTED IMPROVEMENTS: ALREADY ACCOMPLISHED

Implemented improvements are ones that have been fully or partially deployed. Their business plans were submitted and approved years ago. Development work is fully or nearly complete. However, these improvements may still need to be deployed at more locations. Generally, implemented improvements are projected to be fully deployed by 2018.

Figure 2 shows the deployment dates and statuses of implemented NextGen improvements that are captured in this analysis. The years depicted in the table are when the benefits of the operational improvement were assumed to begin accruing. These improvements constitute the foundation of NextGen, the underlying systems and capabilities upon which future improvements will be built.

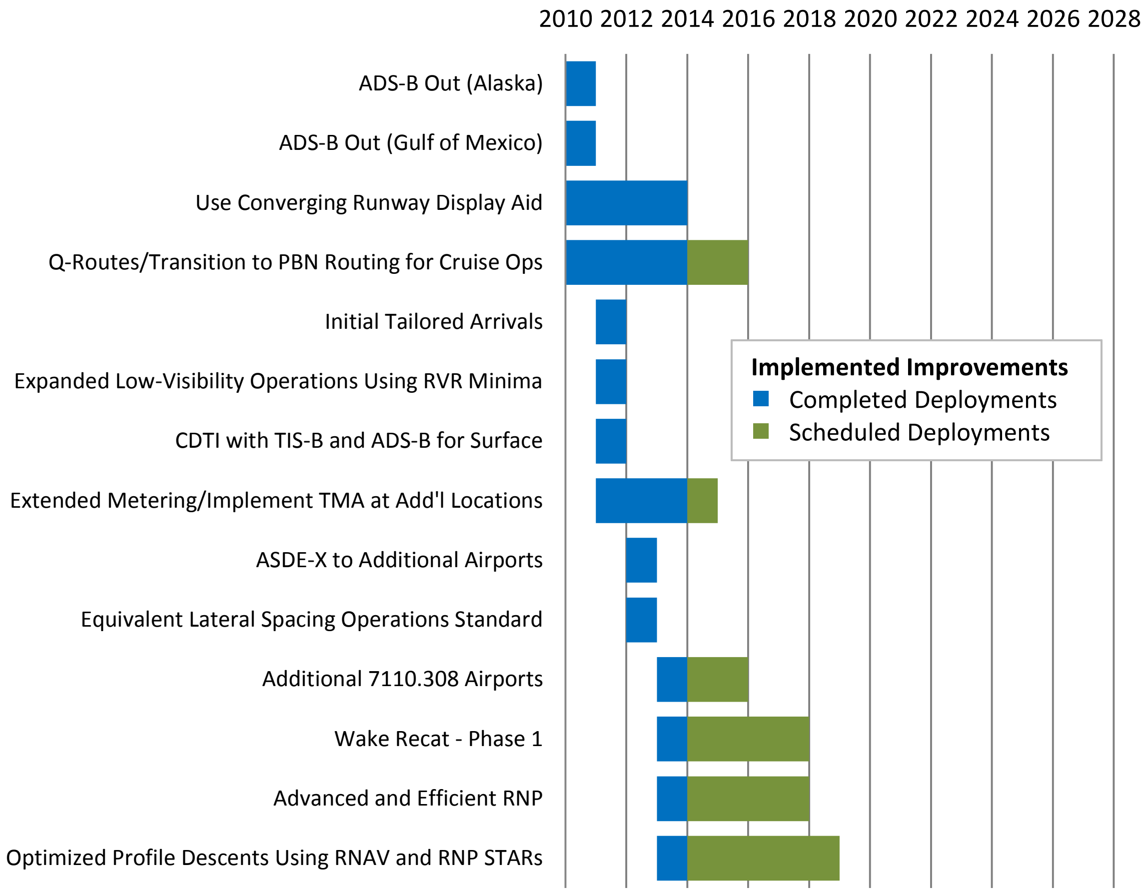

Figure 2 - Benefit Initiation Dates of Implemented NextGen Improvements Captured In This Analysis

Our nation's airways are already realizing benefits from the NextGen's implemented improvements. Through 2014, these new capabilities have provided $1.6 billion in benefits. With full deployment, the implemented improvements are projected to provide an additional $11.7 billion in benefits through 2030.

Realized benefits were determined from synthesized data collected from the most reliable public and proprietary databases available, and applying the most appropriate analytic methods. In some cases, capabilities were defined narrowly enough so that benefits could be directly assessed. In other cases, additional analysis and operational assumptions were needed to properly assess the benefits.

Benefits were quantified by using the latest data and applying widely accepted processing and analysis techniques. The same repeatable and defensible processes were also used to quantify benefits at locations awaiting deployment. Even though the valuation processes have improved significantly over the past several years, they continue to evolve and become more refined. Thus, all realized benefits are subject to change as understanding grows and better data become available.

The general methodology used to estimate realized benefits, along with a more detailed list of assumptions and complete list of monetized benefits, is provided in Appendix A, Estimating the Benefits of Implemented Improvements. Subsequent improvements, development of related procedures and other work may still be required to realize the full anticipated benefits for an implemented improvement.

BASELINED IMPROVEMENTS AND RELATED NEARER-TERM IMPROVEMENTS

Baselined improvements consist of improvements whose business plans and funding have been internally approved. Though work for most is well underway, initial deployment has yet to occur. Generally, baselined improvements are projected for deployment between 2015–2020.

Figure 3 shows the capabilities and planned deployment dates of the baselined improvements captured in this system wide benefits analysis. The years depicted in the table are when the benefits of the operational improvement were assumed to begin accruing. Assuming the baselined improvements are deployed as scheduled, they are expected to deliver $65.1 billion in cumulative benefits by 2030.

The general methodology used to evaluate the baselined benefits, a more detailed list of assumptions and a complete list of benefits are provided in Appendix A, Benefits Methodology.

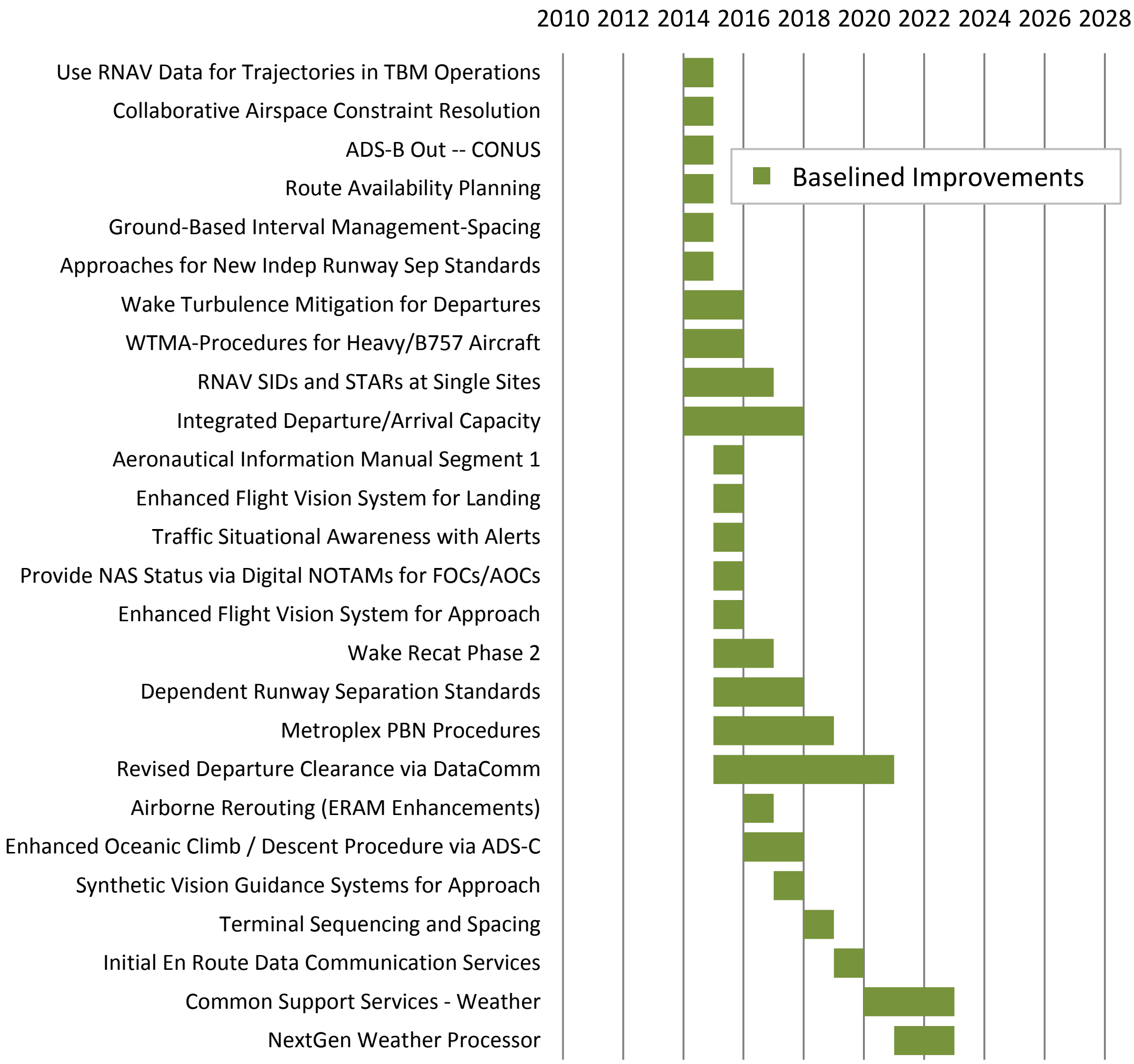

Figure 3 - Benefit Initiation Dates of Baselined NextGen Improvements Captured in This Analysis

ANTICIPATED IMPROVEMENTS: ON THE DRAWING BOARD

NextGen capabilities planned further in the future than the baselined improvements are defined as anticipated improvements. As the name suggests, these are still in the early stages of development. Though preliminary work has begun in individual instances, their business plans have not yet been approved and their funding has not been secured. However, based on preliminary business plans and planning documents, their deployments are expected between 2020 and 2025. These improvements are projected to render $82.2 billion in cumulative benefits by 2030. Figure 4 shows the capabilities and assumed deployment dates of the anticipated improvements captured in this system wide benefits analysis. The years depicted in the table are when the benefits of the operational improvement were assumed to begin accruing.

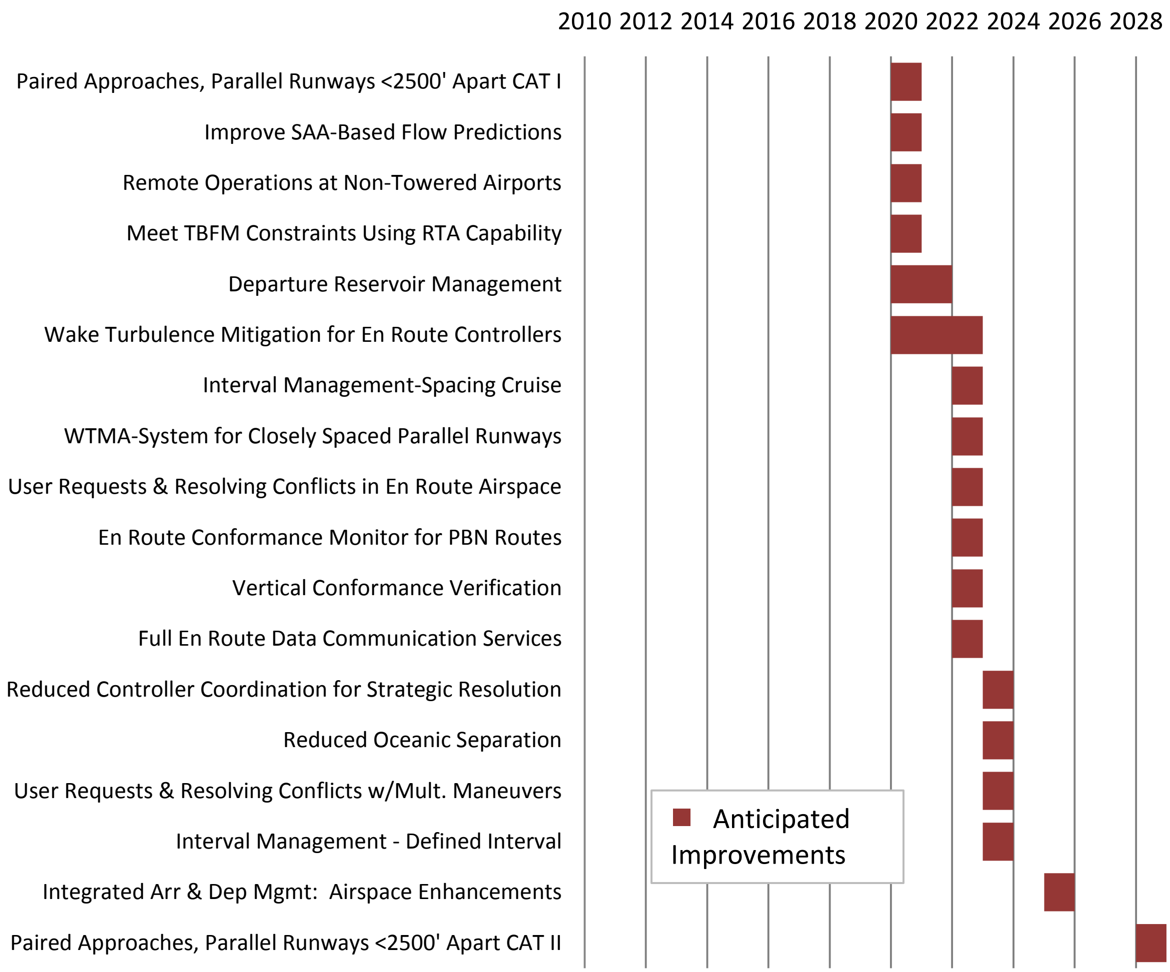

Figure 4 - Benefit Initiation Dates of Anticipated NextGen Improvements Captured in This Analysis

The general methodology used to evaluate the benefits of anticipated improvements, a more detailed list of assumptions and a complete list of benefits are provided in Appendix A, Benefits Methodology.

As already mentioned, anticipated improvements often build upon the implemented and baselined improvements. Delays of key improvements will almost certainly result in delays of anticipated improvements.

ESTIMATED COSTS OF NEXTGEN

Replacing and upgrading the nation's air traffic management infrastructure is a monumental undertaking. Ensuring that NextGen moves forward as scheduled — necessary to deliver promised benefits — will require timely investments from the government and aircraft operators.

Deploying NextGen requires federal government investment in areas such as research and development (R&D), system procurement, airspace and procedure design, training, program management and operations. The FAA's investment in NextGen improvements through 2030 is projected to be $20.6 billion. Using standard budget categories, the costs consist of:

- Capital expenditures from the agency's Facilities and Equipment (F&E) budget are expected to be $16.0 billion.
- Research and other expenditures in the agency's R&D budget line are projected to be $1.5 billion.
- Operations expenses are projected to be $3.1 billion.

Of the total amount, $5.8 billion has already been invested as of 2014. The investment from 2015–2030 is projected to be $14.8 billion. A detailed cost breakdown is shown in Table 2. Further details on the bases of the costs are provided in Appendix B, Cost Methodology.

Table 2 - FAA Costs of NextGen by Phase and Cost Category

Millions, 2015 $		F&E	R&D	Ops	**Total**
Implemented Improvements	Costs to Date (2007–2014)	$700	$0	$100	**$800**
	Future Costs (2015–2030)	N/A	N/A	$500	**$500**
	Total Costs (2007–2030)	**$700**	**$0**	**$600**	**$1,300**
Baselined Improvements	Costs to Date (2007–2014)	$3,400	$400	$100	**$3,900**
	Future Costs (2015–2030)	$2,100	$200	$1,700	**$4,000**
	Total Costs (2007–2030)	**$5,500**	**$600**	**$1,800**	**$7,900**
Anticipated Improvements	Costs to Date (2007–2014)	$1,000	$100	$0	**$1,100**
	Future Costs (2015–2030)	$8,800	$800	$700	**$10,300**
	Total Costs (2007–2030)	**$9,800**	**$900**	**$700**	**$11,400**
All Improvements	**Costs to Date (2007–2014)**	$5,100	$500	$200	**$5,800**
	Future Costs (2015–2030)	$10,900	$1,000	$2,900	**$14,800**
	Total Costs (2007–2030)	**$16,000**	**$1,500**	**$3,100**	**$20,600**

The cost to develop any specific NextGen improvement cannot be directly determined. Single budget line items fund a capability that typically achieves multiple improvements. Thus, separating costs associated with a particular improvement from other improvements sharing a common capability becomes difficult. The occasional need to coordinate development of separate improvements in order to ensure compatibility and overall system integration often results in aggregating funding sources, complicating cost identification even more. Furthermore, developing an improvement requires the assumption that all interdependent capabilities have achieved the required level of operability. For example, TBFM relies on functionality from En Route Automation Modernization (ERAM), Standard Terminal Automation Replacement

System (STARS) and Traffic Management Advisor (TMA). Moreover, full deployment of PBN relies on TBFM.

As Table 2 shows, a total of $800 million has been invested in NextGen implemented improvements through 2014. This includes all capital F&E and R&D expenses. An estimated $500 million of operations expenditures will be required to keep these implemented improvements operational — thereby generating benefits through 2030.

Similarly, Table 2 shows that $3.9 billion and $1.1 billion have been invested in baselined and anticipated improvements, respectively. Most of the capital costs of baseline improvements have already been incurred. Almost half of the remaining cost — $1.7 billion of $4.0 billion — is for maintenance of the baselined improvements' operability. Note that cost estimates for anticipated improvements may be more speculative than the other improvements.

Detailed explanations of F&E, R&D and operations costs can be found in Appendix B, Cost Methodology.

ESTIMATED AVIONICS COSTS

Though the government provides the large majority of NextGen investment, certain capabilities require aircraft operators to upgrade avionics to take full advantage of the benefits. This cost, which includes the purchase and installation of the avionics, has always been included in the Business Case for NextGen.

The total estimated avionics equipage cost is the sum of costs for commercial aircraft and general aviation aircraft. For commercial aircraft, this Business Case uses results from *avionics*Coster, a new costing model developed by the MITRE Corporation that incorporates new methodologies and a new database of costs and commercial aircraft fleets. The *avionics*Coster model considers only the scheduled avionics upgrades by the air carriers (i.e., 14 CFR Part 121). For general aviation aircraft, this Business Case itemizes expected upgrades by examining unit costs and quantities. This is the same method used in the 2014 NextGen Business Case report. Figure 5 illustrates the total annual investment costs for aircraft operators and government.

According to the new *avionics*Coster, the total equipage cost estimate for commercial aircraft through 2030 is $4.9 billion, a decrease of $500 million as reported in the 2014 Business Case for NextGen. The equipage cost estimate for general aviation aircraft (jet, turboprop and piston engine) through 2030 remains constant at $8.9 billion. The unit cost estimates were derived from work done by MITRE in support of the RTCA NextGen Mid-Term Implementation Task Force. These general aviation equipage costs have been used in previous Business Case reports. Moving forward, the general aviation equipage costs analysis in our next report will reflect updated market conditions after FAA's Equip 2020 initiative.

The total avionics cost for the NextGen future improvements is based on assumed capability packages and projected equipage levels within *avionics*Coster. More details on the methodology and assumptions used in the model are provided in Appendix B.

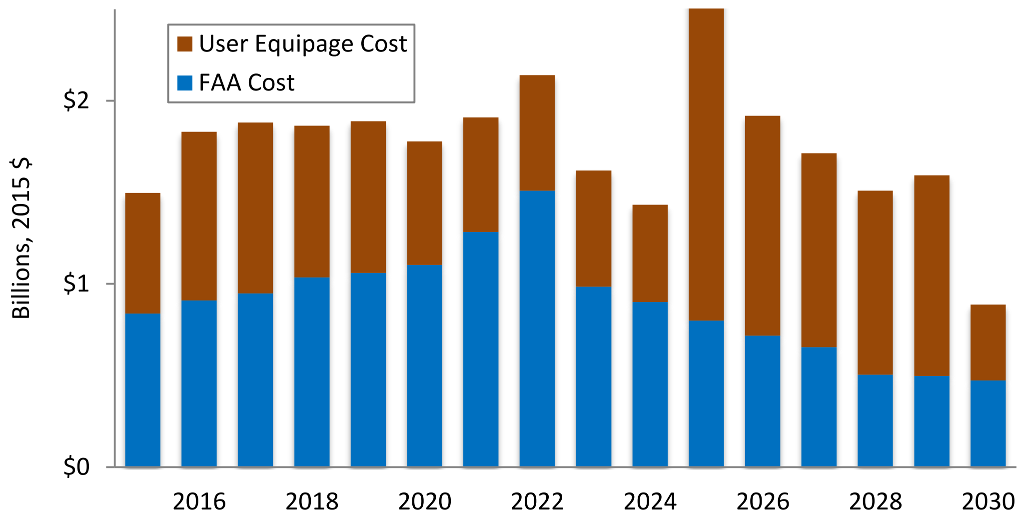

Figure 5 - Annual Cost of NextGen Future Capabilities

ECONOMIC ANALYSIS

In standard investment analysis, future costs and benefits are discounted to reflect decreasing future value. To calculate discounted (or present) values, the Office of Management and Budget (OMB) recommends applying an annual 7 percent discount to benefits and costs that accrue to taxpayers and the private sector[4]. OMB recommends using the current interest rate on U.S. Treasury securities of appropriate term to discount costs and benefits accruing to the government (reflecting the cost of borrowing for the government). Although the majority of costs and some benefits accrue to the federal government, and thus could be discounted at the lower U.S. Treasury bond rate, it is more consistent to use the single discount rate of 7 percent. In general, using a higher discount rate yields more conservative net present value (NPV) than using the U.S. Treasury bond rate.

The cumulative present values of the discounted benefits and costs of implemented improvements are shown in Figure 6. While cash flows occurred between 2008 and 2030, all have been discounted to 2015. Future cash flows have been treated as normally discounted cash flows, and historical cash flows have been increased, or "negatively discounted," to reflect the value of those flows in 2015. While this is a somewhat untraditional treatment, it is necessary to capture all lifecycle costs and benefits of NextGen.[5] As can be seen, the implemented

[4] United States Office of Management and Budget, *Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, https://www.whitehouse.gov/omb/circulars_a094/.

[5] Alternatively, all costs and benefits could have been discounted back to 2008. The benefit-to-cost ratio and breakeven year would be identical using this approach, although the Net Present Value (NPV) would be different.

improvements achieved breakeven in 2013, when cumulative benefits exceeded cumulative costs. In each subsequent year, benefits grow faster than costs, so the investment picture improves with time. The NPV of the implemented improvements is $7.5 billion, meaning by 2030, the cumulative benefits will have exceeded the cumulative costs by $7.5 billion. The benefit-to-cost ratio is 6.5-to-1.

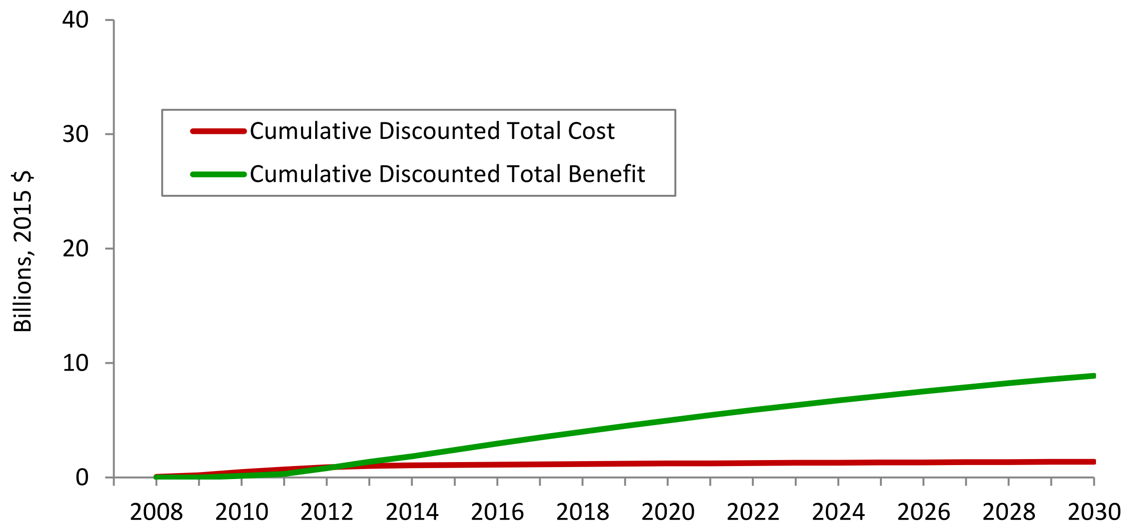

Figure 6 - Discounted Cumulative Benefits and Costs of Implemented Programs

Figures 7 and 8 show the discounted benefits and costs of baselined and anticipated improvements, respectively. As before, the cumulative present value of all cash flows is provided — future and historical — in 2015 dollars. The baselined improvements achieve breakeven in 2021, with an NPV of $21.8 billion and a benefit-to-cost ratio of 2.5-to-1. The anticipated improvements achieve breakeven in 2025, with an NPV of $25.2 billion and a benefit-to-cost ratio of 3.1-to-1. Figure 9 illustrates the annual net present values without considering the passenger value of time (PVT) savings. Appendix A provides more details about PVT. Excluding these savings, NextGen still results with a positive benefit-to-cost ratio of 1.0, and NPV of -$377 million.

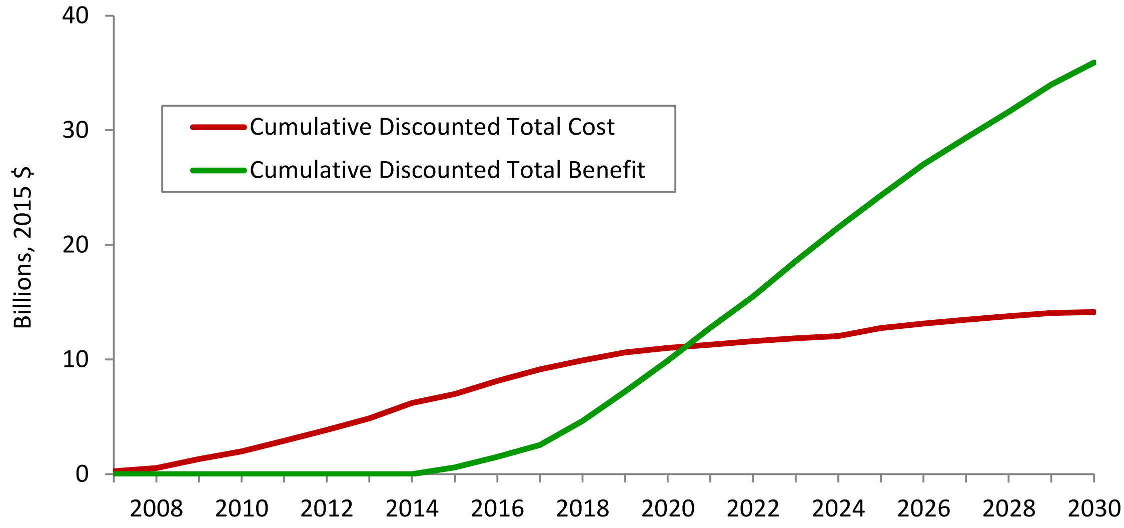

Figure 7 - Discounted Cumulative Benefits and Costs of Baselined Programs

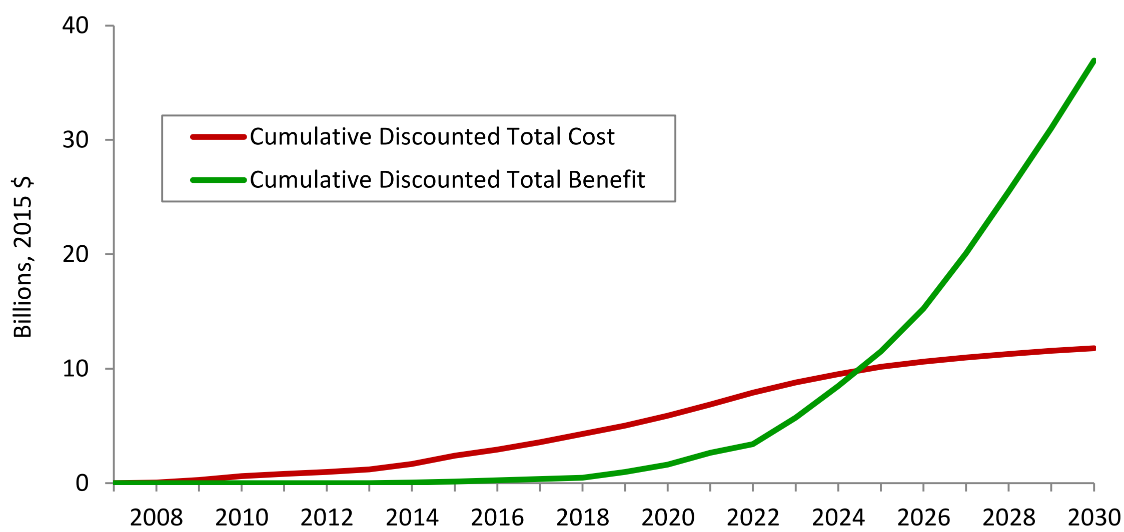

Figure 8 - Discounted Cumulative Benefits and Costs of Anticipated Programs

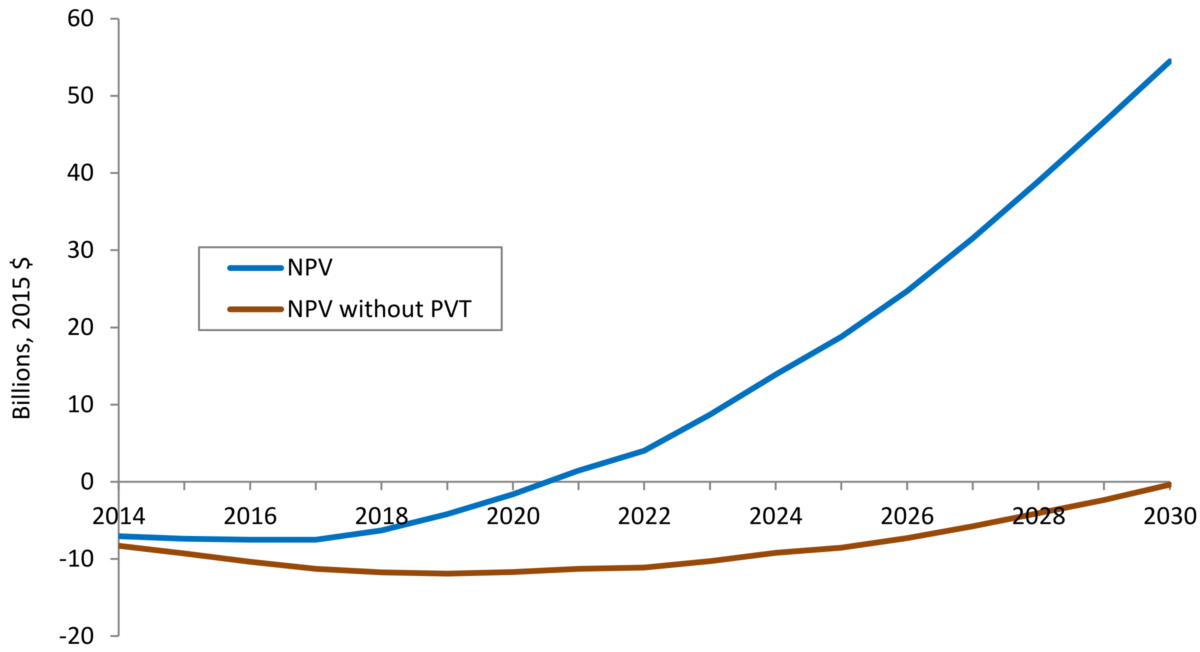

Figure 9 - NextGen Investments' Net Present Value by Year

When analyzing the financial performance of NextGen investments, it is worth noting this Business Case's timeframe for benefits accumulation ends in 2030 to be consistent with previous versions and to provide a conservative benefits outlook. As seen in Figure 4, most anticipated improvements will be implemented on or after 2022. Despite their late start, anticipated improvements are projected to account for benefits of $87.6 billion by 2030. Though more than half the benefits of all NextGen improvements, this represents only a small portion of their eventual benefits. For most major investments the FAA examines a 20–25 year lifecycle benefit-cost analysis. As anticipated improvements realize their benefits potential, annual costs reduce sharply in 2025 and continue to shrink thereafter, as seen in Figure 5 on page 17. Thus the NPV of NextGen investments, both with and without PVT, is expected to continue increasing after 2030.

CONCLUDING THOUGHTS

The goal of NextGen is to transform U.S. air transport to meet the demands of the 21st century. This transformation will be achieved through a series of improvements: R&D, system procurement, airspace and procedure design, training, program management, operations and new aircraft avionics. In producing this Business Case for NextGen, benefits are linked to their required investments and activities. Every effort was made to capture all relevant costs and benefits.

A summary of the financial analyses for these improvements is shown in Table 3. By 2030, NextGen improvements are expected to deliver an overall benefit-to-cost ratio of 3.0-to-1, meaning every $1 invested in NextGen will deliver $3 of benefits. All implemented improvement costs have all been incurred; only ongoing operations costs remain. Likewise, most baselined improvements' capital costs have been incurred and nearly half of the remaining future costs are also for operations, which are projected to return $65.1 billion in benefits. Anticipated improvements are projected to yield $82.2 billion in benefits by 2030. Note that the anticipated programs deploy between 2020 and 2025; in a 10-year timeframe they deliver more benefits than the implemented and baselined improvements combined. Furthermore, anticipated programs will develop their own investment analysis and business cases for deployment.

Table 3 - Financial Results of Improvement Groups

Billions, 2015 $	Past (2007–2014)	Future (2015–2030)	Total (2007–2030)	NPV	Benefit/Cost Ratio	Breakeven Point
Implemented Improvements	Costs $0.8 Benefits $1.6	Costs $0.5 Benefits $11.7	Costs $1.3 Benefits $13.3	$7.5	6.5 : 1	2013
Baselined Improvements	Costs $5.0 Benefits N/A	Costs $12.0 Benefits $65.1	Costs $17.0 Benefits $65.1	$21.8	2.5 : 1	2021
Anticipated Improvements	Costs $1.4 Benefits N/A	Costs $16.1 Benefits $82.2	Costs $17.5 Benefits $82.2	$25.2	3.1 : 1	2025
Overall NextGen	**Costs $7.2** **Benefits $1.6**	**Costs $28.6** **Benefits $159.0**	**Costs $35.8** **Benefits $160.6**	**$54.5**	**3.0 : 1**	**2021**

The authors of the Business Case strive to improve all of its aspects: identifying realized benefits, forecasting future benefits and identifying pertinent costs. Future versions of the Business Case may change as methodologies improve and expectations of future traffic and capacity evolve.

U.S. civil aviation is a substantial portion of the U.S. economy — generating 5.4 percent of U.S. gross domestic product and 11.8 million jobs[6] — and a major economic driver. A NAS that accommodates increased capacity while maintaining its safety record could serve as a catalyst for economic growth. For this reason and the positive financial return on NextGen, the Business Case concludes that NextGen is a sound investment.

[6] Federal Aviation Administration, *The Economic Impact of U.S. Civil Aviation on the U.S. Economy* (June 2014), http://go.usa.gov/x3FyA.

APPENDIX A: BENEFITS METHODOLOGY

ESTIMATING THE BENEFITS OF IMPLEMENTED IMPROVEMENTS

For this report, NextGen progress is defined by operational improvements (OI) and, on a more granular level, by OI increments. The FAA is responsible for quantifying benefits when an OI or OI increment is achieved. Though each benefit study in this section represents a unique individual analysis customized for its own situation, all follow the same general process.

Most of these studies begin with site-specific operational analyses conducted by or for the FAA. These studies tend to focus on the impacts of one improvement at one or more airports, metroplexes or regions. For example, most benefit studies in this section were direct follow-on analyses based on the FAA's annual NextGen Operational Performance Assessment[7].

Next, the improvement's benefit(s) are assessed. Some benefits can be measured directly, while others need additional analysis and operational assumptions to be properly quantified. Great care is taken to ensure the operational benefit that is being assessed is attributed to the appropriate operational improvement. To avoid confounding factors, other operational improvements must not have been implemented at the same time and locations. "Time saved" or "reduced distances flown" are the most common operational benefits.

Two general methods of assessing benefits are: directly comparing flights at the sites before and after the improvement was implemented, or concurrently comparing flights at the sites with and without the capability. Availability of data, implementation timelines and operational complexity all influence the choice of analytical method.

The data used, be it historical or current, comes from the most reliable sources available. Generally, authoritative FAA databases are preferred, using real, operational data with, for example, Traffic Flow Management System Aviation Support Performance Metrics, but these are sometimes supplemented with contractor-maintained proprietary databases and systems, for example Performance Data Analysis and Reporting System.

The most current and suitable analytical methods and statistical analyses were applied to identify realized savings to other similar sites within the NAS for the similar time periods, as appropriate. Also, depending on the period when data were collected, benefits may be delayed by as much as one year, necessitating adjustments or assumptions.

From this, a monetized future benefit can be derived. The two largest stakeholders are the air carriers and the flying public. Two key performance measures frequently used are aircraft operating expenses and passenger travel time. The associated standard economic factors used for the calculations are aircraft direct operating costs (ADOC) and the PVT. Guidance on these values is provided by FAA's Office of Policy and Plans; Office of Investment, Planning and

[7] Federal Aviation Administration, *Operational Performance Assessment* (September 2015), faa.gov/nextgen/media/ngpa_2015.pdf.

Analysis; and the U.S. Department of Transportation Office of Transportation Policy. ADOC considers costs to the air carriers associated with crews, fuel and oil, maintenance, rentals and depreciation. PVT considers the opportunity cost of passenger time — how much a person would value time savings (see PVT section later in this Appendix for more details).

Finally, in combination with applicable traffic forecasts and other operational assumptions, the monetized benefits are projected to 2030 for the sites with OIs already implemented. The expansion or enhancement of an operational improvement beyond current plans is not considered here (e.g., more sites added or additional capability). However, projected changes in air traffic, procedure utilization or avionics equipage are taken into account.

Table 4 lists the capabilities that have either been partially or fully implemented and were used to estimate the benefits achieved in this report.

Table 4 - Portfolio Operational Improvements Used to Calculate Benefits Achieved

Portfolio	Improvement or Operational Improvement Increment (OI Increment #)
ADS-B	Reduction in Alaskan Accidents
	Gulf of Mexico Low-Altitude Efficiency
Surface	Airport Surface Detection Equipment–Model X to Additional Airports (103207-12)
Time Based Flow Management	Implement Traffic Manager Advisor and Adjacent Center Metering at Additional Locations (104115-11,-12)
Improved Multiple Runway Operations	Use Converging Runway Display Aid (108209-16)
	Additional 7110.308 Airports (Closely Spaced Parallel Runways) (102141-11)
Improved Approaches and Low-Visibility Operations	Initial Tailored Arrivals (104124-11)
	Optimized Profile Descents using Area Navigation Standard Terminal Arrivals (104124-12)
	Expanded Low-Visibility Operations Using Lower Runway Visual Range Minima (107119-01)
Performance Based Navigation	Required Navigation Performance Authorization Required Approaches (107103-12)
	Transition to PBN Routing for Cruise Operations (108209-14)
	Equivalent Lateral Spacing Operations (108209-21)
Separation Management	Wake Recategorization - Phase I (SDF, MEM, ATL, CVG) (102143-11)

ADS-B in Alaska and the Gulf of Mexico

ADS-B is a data link system in which aircraft avionics broadcast the position and other information from the aircraft for ground-based receivers and other aircraft with receivers. This system enables the FAA to provide surveillance and separation services to equipped aircraft in areas where radar coverage is impossible, increasing safety and efficiency.

The first ADS-B analysis considered in this Business Case examined low-altitude helicopter flights in the Gulf of Mexico between 2010–2011. The average distance saved per flight was monetized for PVT and ADOC, and projected savings used modest assumptions for growth in traffic and utilization.

The second analysis examined ADS-B equipped air charters and air taxis in Alaska between 2010 and 2013. The reduction in accident rates between equipped and non-equipped aircraft was then monetized using values for aircraft damage and personal injuries. For the purpose of forecasting benefits, this analysis held equipage rates and accident rates constant at the 2013 values while allowing for traffic growth.

Airport Surface Detection Equipment–Model X

Airport Surface Detection Equipment–Model X (ASDE-X) is a surveillance system using radar and satellite technology that allows air traffic controllers to track surface movement of aircraft and vehicles. The system was designed to help reduce runway incursions.

This analysis was based on data from 2010 where the actual number of severe runway incursions at ASDE-X equipped airports was 20 percent lower than the number projected without ASDE-X. Monetized benefits were derived using the relationship between runway incursions and the probability of a resulting accident, based on historical data.

Time Based Flow Management

TBFM is used to manage arrival flows to 24 of the 30 major U.S. airports. Two key functions of TBFM are Airborne Metering and Departure Scheduling, which were examined in this analysis. Airborne metering assigns runways, schedules landing times, computes and allocates airborne delays, and shares its schedule and delay information with en route controllers at their workstations. Departure scheduling allows traffic managers to more efficiently manage arrival times at destination airports by calculating and adjusting departure times at their origins.

This analysis was based on data from 2011–2013 and found reductions in ground times for departures employing departure scheduling as well as a reduction in airborne times where airborne metering was used. The following airports were included in this analysis: Atlanta, Detroit, Fort Lauderdale, Las Vegas, Newark, New York LaGuardia, Philadelphia and San Francisco.

Converging Runway Display Aid

The Converging Runway Display Aid (CRDA) is an automation tool used by air traffic controllers to manage the sequence of arrival flows on converging or intersecting runways. Savings are based on the assumption that a ground delay program would be used if the CRDA were not available. In other words, the CRDA enhances an airport’s effective throughput under certain conditions.

This analysis studied the impact of CRDA use on operations at Boston following CRDA implementation. The average savings were determined from the flight time difference during specific operating conditions with and without CRDA. Since this tool is designed for use during times of constrained capacity, only the "busy" periods (defined as noon-8 p.m.) were examined. Time savings found were then applied to Newark, where CRDA is also in place. Savings calculations were then extended through 2030 for Boston and Newark.

Additional 7110.308 Airports (Closely Spaced Parallel Runways)

In October 2012, San Francisco was added to FAA Order 7110.308. This order allows dependent instrument approaches to specific parallel runways with centerline spacing of less than 2,500 feet, known as Closely Spaced Parallel Runways (CSPR). The procedure does not require any specific aircraft equipment or performance capabilities, but it does require extensive safety review and controller training.

This analysis found the new dual CSPR approaches reduced departure and arrival delays during Instrument Meteorological Conditions when only single-runway approaches were possible in the past.

Initial Tailored Arrivals

Tailored Arrivals (TAs) are planned, fixed routes for aircraft making their approach to an airport from oceanic airspace that are communicated via a data link from the air traffic controller. Once accepted by the aircraft, the route is downloaded to the aircraft's flight management system quickly and without error.

This analysis studied the impact on operations at San Francisco and Los Angeles following TA implementation. The average savings were determined from the difference between time spent in level flight relative to non-TA flights, based on two assumptions: by spending less time in level flight on arrival, TAs burn less fuel, and TAs and non-TAs have their engines adjusted to near-idle speed while descending. Time savings were then applied to Miami, where TAs were also in use, and then extended through 2030 for all three airports.

Optimized Profile Descents Using Area Navigation

Optimized Profile Descents (OPDs) are a class of Area Navigation (RNAV) instrument arrival procedures which enable aircraft to descend from cruise altitude to final approach at or near idle power with few, if any, level offs.

This analysis examined the airports where 41 RNAV Standard Terminal Arrival (STAR) procedures with OPDs were implemented in Fiscal Year 2013. The analysis revealed an overall 8 percent reduction in time in level flight and nearly twice as many flights using OPDs with no level segments at all. Benefits were monetized by computing fuel savings from more OPDs as well as from reduced level segments.

Benefits for the following airports are included: Albuquerque, Atlanta, Charlotte, Chicago Midway, Denver, Nashville, Portland, Raleigh-Durham, Seattle, St. Louis and Teterboro in New Jersey.

Reducing Runway Visual Range Minimum Requirements

Expanded Low-Visibility Operations (ELVO) is a low-cost infrastructure program designed to reduce ceiling and runway visual range (RVR) minima through a combination of ground equipment and procedures. ELVO makes use of existing aircraft avionics such as head up displays and autoland. As of May 2012, Category (CAT) I and CAT II special authorization capabilities had been added to 40 runway ends.

This analysis examined ELVO-enabled airports before and after 2010 and found a decrease in arrival delays with a corresponding increase in airport access. For purposes of this analysis, avionics equipage was held steady at 2010 levels. This additional airport access and delay savings was valued using ADOC and PVT, where New York LaGuardia appears to be the biggest beneficiary, with more than $1 million per year in benefits from additional aircraft access.

Required Navigation Performance Authorization Required Approaches

Required Navigation Performance (RNP) Authorization Required (AR) approaches are instrument approach procedures that are more precise than RNAV or conventional approaches. They require monitoring and alerting functions, and may be conducted only by aircrews meeting special training requirements in aircraft that meet specified performance and functional requirements. RNP AR approaches are typically used to avoid obstacles, restricted airspace or traffic from nearby airports.

This analysis studied the impact of RNP AR approaches throughout the NAS, but was limited to only those procedures that include the signature of a defined turn-to-final leg. A total of 172 procedures were analyzed. The average time savings per flight was calculated relative to comparable flights that flew conventional approaches. For this analysis, changes in utilization and equipage were considered, as well as any growth in air traffic. This analysis did not take into account any increase in RNP AR procedures.

Transition to PBN Routing for Cruise Operations

Q-Routes are published high-altitude routes available for use by RNAV-equipped aircraft. These PBN routes are designed to alleviate airspace complexity in en route or cruise altitude corridors with high traffic volume and enhance the predictability of traffic flows in these corridors.

This analysis examined the NAS-wide impact of using Q-Routes through FY 2013. Since it is difficult to know how many Q-Route flights were flown, for purposes of this analysis the number of Q-Routes requested were assumed to approximate the number of Q-Route flights. This analysis found that, on average, aircraft requesting Q-Routes in their flight plans flew shorter distances (almost 14 nautical miles) and experienced reduced arrival delays (about 2 minutes).

Equivalent Lateral Spacing Operations Standard

Equivalent Lateral Spacing Operations (ELSO) reduce the required angle for departures that use RNAV Standard Instrument Departures (SIDs). It is a modification to the conventional divergence requirement that capitalizes primarily on improved navigational precision of PBN operations. In FY 2012, the FAA published RNAV SIDs for Atlanta to take advantage of ELSO. These new ELSO procedures provided an additional departure route in each direction, which was not possible before. This analysis found less reliance on the distant south Runway 10/28 and a reduction in average taxi times for all flights by 2.5 minutes.

Wake Separation Categorization

Until recently, the FAA categorized aircraft into five broad wake turbulence categories for approach and departure operations. These categories often resulted in longer than necessary separation distances between aircraft. Following more than a decade of research by the FAA, NASA, EUROCONTROL, the International Civil Aviation Organization and industry partners, six new categories were developed. The expansion to six categories supports reduced separation between some lead-trail pairs, resulting in increased overall throughput.

Memphis was the first site to adopt the new Wake Recat standards in November 2012, followed by Louisville in September 2013, Cincinnati/Northern Kentucky in March 2014 and Atlanta in June 2014.

This analysis found that runway capacity increases reduced departure taxi times and flight times in Terminal Radar Approach Control airspace for arrivals.

Summary

Table 5 summarizes the estimated benefits of implemented improvements contained in the Business Case.

Table 5 – Life Cycle Benefits of Implemented Improvements
(Millions, 2015 $)

Improvement (Program) / OI Increment (OI Increment #)	Benefits to Date (2010–2014)	Future Benefits (2015–2030)	Total Benefits (2010–2030)
Programs			
Reduction in Alaskan Accidents (ADS-B)	$175	$774	**$940**
Gulf of Mexico Low-Altitude Efficiency (ADS-B)	$4	$22	**$26**
Surface Portfolio			
ASDE-X to Additional Airports (103207-12)	$35	$533	**$568**
TBFM Portfolio			
Implement TMA and ACM at Additional Locations (104115-11,-12)	$641	$4,020	**$4,661**
IMRO Portfolio			
Additional 7110.308 Airports (Closely Spaced Parallel Runways) (102141-11)	$39	$805	**$845**
Use Converging Runway Display Aid (CRDA) (108209-16)	$7	$37	**$43**
Improved Vertical Profiles and Low-Vis Operations			
Initial Tailored Arrivals (104124-11)	$2	$44	**$46**
Optimized Profile Descents Using RNAV and RNP STARs (104124-12)	$4	$95	**$99**
Expanded Low-Visibility Ops Using Lower RVR Minima (107119-01)	$24	$123	**$148**
PBN Portfolio			
RNP and RNP AR Approaches (107103-12)	$0.3	$2.1	**$2.4**
Transition to PBN Routing for Cruise Operations (108209-14)	$291	$1,127	**$1,418**
Equivalent Lateral Spacing Operations (108209-21)	$339	$2,234	**$2,573**
Separation Management			
Wake Recat - Phase 1 (SDF, MEM) (102154-11)	$12	$218	**$229**
Wake Recat - Phase 1 (ATL) (102154-11)	N/A	$1,615	**$1,615**
Wake Recat - Phase 1 (CVG) (102154-11)	$0.5	$15	**$16**
All Portfolios	**$1,575**	**$11,664**	**$13,239**

ESTIMATING FUTURE BENEFITS USING FAA'S SYSTEM WIDE ANALYSIS CAPABILITY

The FAA estimates the benefits for NextGen improvements yet to be implemented with simulation modeling. The benefit of NextGen improvements is the difference between the simulated model performance of a NAS base case (no further NextGen improvements implemented) and NAS with new NextGen improvements. The base case includes currently implemented NextGen improvements with planned runway extensions and additions. For this report, two NextGen performance scenarios are evaluated: the base case with baselined improvements, and the base case with baselined and anticipated improvements.

The FAA's System Wide Analysis Capability (SWAC) is a fast-time simulation model that estimates expected operational benefits of NextGen improvements for the NAS. SWAC can calculate delay, canceled flights and fuel burn savings along with the potential for an increase in overall air traffic made possible by the various NextGen mid-term improvements working together.

At its core, SWAC is a discrete event-queuing model. NAS resources that may be capacity constrained — such as sectors, arrival or departure fixes, or airports — are represented as servers in the queuing model. SWAC contains server representations for all en route sectors in contiguous U.S. airspace, 310 domestic airports, terminal airspace at the 35 busiest airports and in-trail constraints for aircraft entering oceanic airspace[8]. To represent the demand on those servers, each flight is modeled at a detailed level.

To generate the traffic demand on NAS resources, SWAC begins with actual flight data from the FAA's Traffic Flow Management System. Drawing from a representative set of historical days, all flights that filed an Instrument Flight Rules (IFR) flight plan and flew in the NAS are gathered as the baseline set of flights[9]. These flights are then augmented with Visual Flight Rules arrivals and departures from the FAA Operations Network data. Current traffic levels are also projected into future years using the FAA Terminal Area Forecast[10]. If this future traffic projection leads to demand at any airport that is infeasible given the airport's capacity, then flights are removed. Such flights are assumed not to be scheduled and flown[11].

When looking at future scenarios, the FAA's airline fleet guides change to the fleet modeling. This is mainly done to more accurately represent future fuel usage and carbon dioxide emissions. These aircraft are also modeled as having a certain avionics equipage, which changes over time.

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[8] SWAC represents all IFR flights that enter, exit, or transition through U.S.-controlled airspace. However, some U.S. airports (310 for this analysis) are capacity constrained in the model. All other airports are assumed to have infinite capacity.

[9] For this analysis, a set of 16 days from FY 2013 was used to represent the entire year. These days were selected using an optimization technique to ensure that derived annual totals for airports, air route traffic control centers and oceanic regions are as close to observed values as possible.

[10] Federal Aviation Administration, *Terminal Area Forecast: Fiscal Years 2013–2040* (2015), http://go.usa.gov/x3FJW.

[11] When NextGen improvements are projected to increase capacity at constrained airports, some removed flights may be added back in, which becomes a quantifiable benefit.

This equipage may be NextGen-related and can be used to modify a planned flight route. (For example, Q-Routes can be selected and continuous ascent/descent profiles specified). Equipage may also affect how specific aircraft interact with model resources, such as airspace sectors and airports. Each IFR flight has its trajectory computed and interpolated in 4-D using EUROCONTROL's Base of Aircraft Data (BADA)[12], using historical data on winds aloft for the particular day being modeled[13]. These interpolated trajectories, combined with assumptions about aircraft type, allow for detailed estimates of time in flight and fuel used.

Along with demand, capacity is a key component of the model. Sector capacity estimates are based on traffic flow management monitor alert parameters and are modified during simulation execution using National Convective Weather Diagnostic data. Airport capacities are estimated using MITRE's *runway*Simulator model for at least three surface weather conditions for each airport: visual, marginal visual and instrument. Meteorological Aerodrome Report data are then used by SWAC to determine local airport conditions and which airport arrival and departure capacities to use at any given time during the simulation. Historical weather data is obtained from the National Weather Service's National Climatic Data Center.

As the queuing simulation model is run, an algorithm determines if, in the case of bad weather, any ground delay programs should be implemented. By shifting delay to the surface that might otherwise have been taken in the air, this computation allows for more accurate estimates of flight time, fuel usage and sector congestion. Resultant delays and corresponding fuel burn can be computed. The differences in flight times, scheduled flights and canceled flights between the NextGen Case and the base case represent the impact of NextGen. The valuation of these differences in dollar terms is covered in the Benefit Valuation Methodologies section.

The largest modeled benefits come from reduced delays. Although models show a marked improvement in delay minutes compared to a future without NextGen, delays nevertheless are expected to increase. This is an unavoidable consequence of FAA-forecasted air traffic increases over the next 20 years. However, the increase with NextGen is less steep, as shown in Figure 10.

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[12] EUROCONTROL, *User Manual for the Base of Aircraft Data (BADA) Revision 3.11, EEC Technical/Scientific Report No. 13/04/16-01* (May 2014), eurocontrol.int/services/bada.

[13] The National Centers for Environmental Prediction/National Center for Atmospheric Research Global Reanalysis Model provided wind and pressure estimates for the SWAC trajectory model.

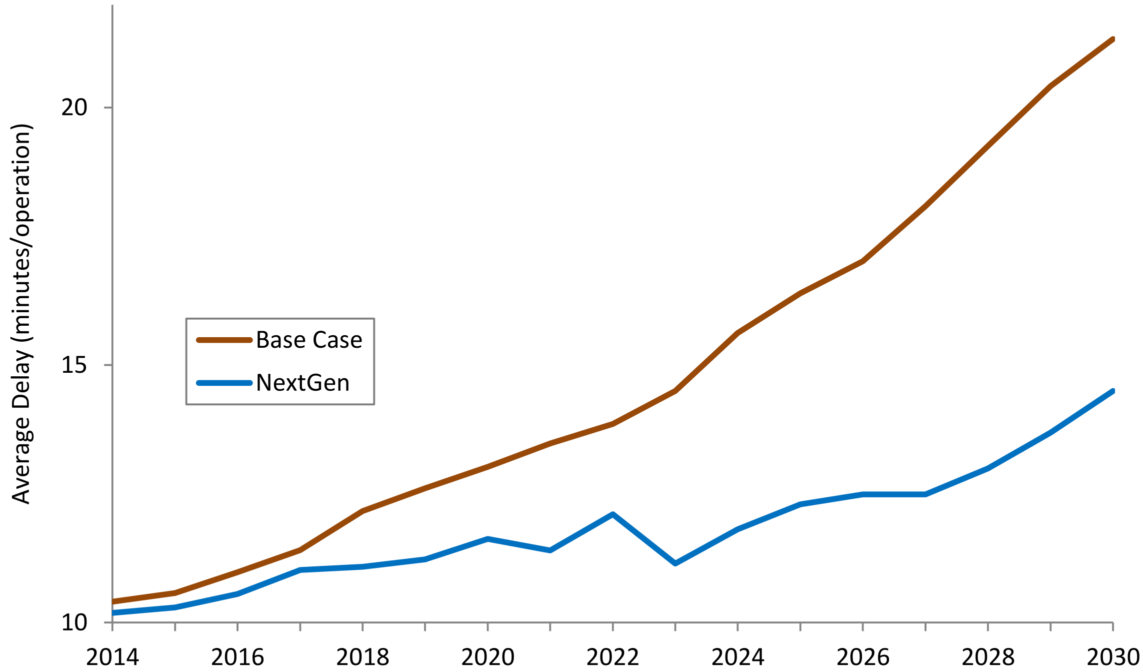

Figure 10 - Projected Average Delay Per Flight From SWAC

BENEFIT VALUATION METHODOLOGIES

Valuing Modeled Improvements in NAS Performance

Differences between modeled performance with and without NextGen improvements are estimated in the following categories:

- Improvements in system capacity utilization
    - Reductions in flight, taxi and gate times and corresponding fuel use resulting from reduced delay
    - Reductions in canceled flights
    - Additional scheduled flights that are enabled by increased effective airport capacity
- Improvements in system efficiency through reductions in flight times and fuel use due to more direct routings, and more efficient climb and descent profiles

Valuing Reductions in Flight Times and Fuel Use

To evaluate the monetary value of changes in flight times, this Business Case applies the FAA's standard method of using ADOC and PVT. This method is applied to any change in flight time — whether due to reductions in delay or improvements in flight efficiency.

Airline Direct Operating Costs (ADOC)

ADOC is used to estimate the impact of changes in flight times on aircraft operators. The FAA's official ADOC values[14] include the costs of fuel, oil, crew and maintenance per hour of operation for large passenger carriers, and cargo, military and general aviation. Because the SWAC model estimates fuel use directly, the ADOC fuel cost component can be replaced with the more accurate model-estimated fuel consumption. Other ADOC value components are further tailored by considering the specific aircraft type and user class as modeled in SWAC[15]. The value of time and fuel savings for aircraft operators is the sum of crew, maintenance and fuel costs given by the formula:

$$\textit{Value of Time Savings}\ (ADOC) =$$

$$\sum_f \left[\textit{minutes saved}_f \times \left(\frac{\textit{crew and maintenance cost}}{\textit{minute}} \right)_{a,u} \right] + \sum_f \left[(\textit{excess fuel use})_f \times (\textit{jet fuel price}) \right]$$

Where

f = flight segment

a = BADA aircraft type

u = user class (commercial passenger service, cargo, etc.)

Passenger Value of Time (PVT)

Based on the latest Department of Transportation guidance, each hour of passengers' time is valued at $47.30 in 2015, with 1.6 percent real growth each subsequent year[16]. Combining these PVT estimates with seat count and load factor estimates, the value of reduced flight time for passengers is calculated by:

$$\textit{Value of Time Savings}\ (PVT) = \sum_f \left[\textit{minutes saved}_f \times \frac{PVT}{\textit{minute}} \times \textit{seats}_{a,u} \times \textit{load factor}_u \right]$$

Where

f = flight segment

a = BADA aircraft type

u = user class (commercial passenger service, cargo, etc.)

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[14] Federal Aviation Administration, *Economic Values for FAA Investment and Regulatory Investment Decisions: A Guide* (2007), faa.gov/regulations_policies/policy_guidance/benefit_cost.

[15] For new aircraft types that are not yet in service, modeling was based on a surrogate aircraft. Fuel cost was scaled by the estimated fuel consumption of the new aircraft. Crew and maintenance costs were estimated based on the new aircraft's anticipated seat count.

[16] *Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis* (9/28/2011), http://go.usa.gov/x3FJF.

Valuing Carbon Dioxide Reductions

Reduced flight times and delays also reduce fuel use. NextGen improvements are estimated to save 2.8 billion gallons of fuel through 2030. While the direct cost of fuel to aircraft operators is already included in the ADOC calculations above, the environmental benefits to society as a whole are not.

Using a standard conversion formula, fuel savings translate to unreleased carbon dioxide. Applying the social cost of carbon (SCC) yields a monetized value. The U.S. Interagency Working Group on the Social Cost of Carbon established the SCC valuations by year along with appropriate discount rates to use for each year[17]. The benefit valuation is given by the following formula:

$$Value\ of\ CO_2\ Reduction =$$

$$(gallons\ of\ \ fuel\ saved)_y \times \left(\frac{21.095\ lbs\ CO_2}{gallon\ of\ \ fuel}\right) \times \left(\frac{1\ metric\ ton}{2204.62\ lbs\ CO_2}\right) \times (SCC_y)$$

Where

y = year

Valuing Additional Flights

Capacity increases — allowing additional flights to be scheduled and flown — can be very beneficial. This is particularly true at capacity-constrained airports if capacity limits are in fact restricting demand. However, care must be taken when valuing these additional flights. It would be incorrect to simply count additional revenue generated (e.g., the average ticket price multiplied by the number of additional passengers served). In general, air carrier revenue is a transfer from passengers to flight operators in exchange for a service provided. If the service was not provided, passengers would have spent their money elsewhere.

A more accurate estimate of the benefit of additional flights is provided by applying the concept of consumer surplus. While a thorough treatment of consumer surplus is beyond the scope of this Business Case, this surplus reflects consumers' "willingness to pay" for a product or service. In general, many consumers are willing to pay more than the market price for the service, in this case air transportation. The sum total of this willingness to pay across all consumers in the market is the consumer surplus. If the cost to consumers goes down, consumer surplus increases because more people pay less than they otherwise would for the same service.

Additional flights are expected in a NextGen future because reducing the cost of providing these flights should translate to decreased ticket prices. In this case, the decrease in cost is brought about by reduced delays. Thus, new flights are valued using the marginal reduction in delay cost,

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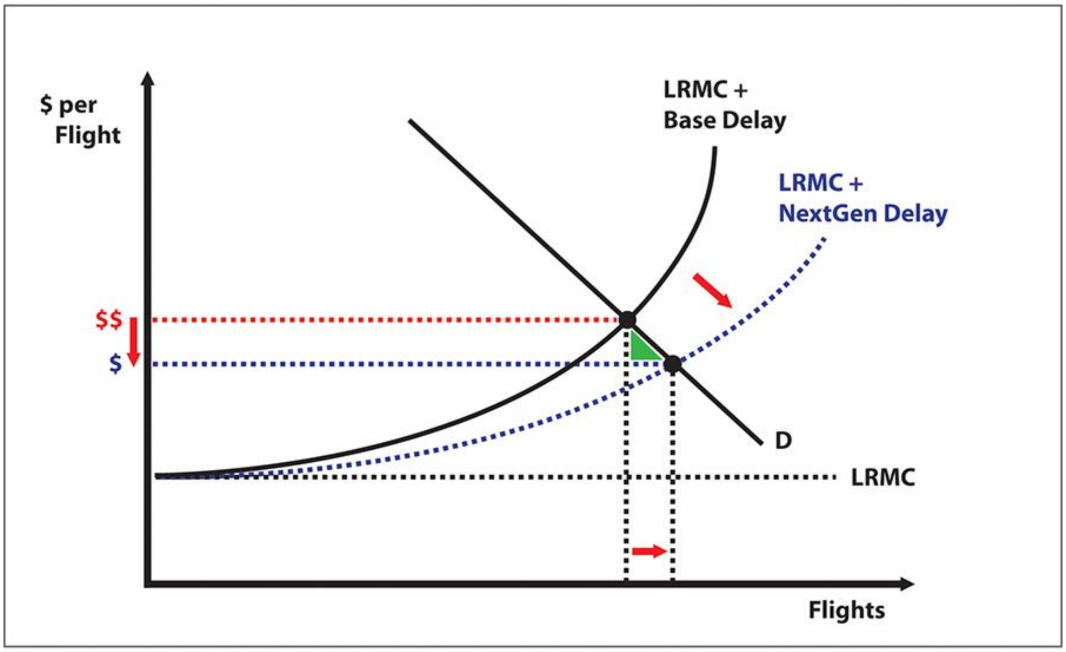
[17] United States Government Interagency Working Group on Social Cost of Carbon, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, p. 28 (2010), epa.gov/otaq/climate/regulations/scc-tsd.pdf. Values used by FAA Systems Analysis are taken from Table 4 assuming a 3 percent discount rate.

multiplied by the marginal increase in the number of flights enabled by this delay cost reduction. Graphically, this is the area under the demand curve between the old and new number of flights, as shown in Figure 11.

Additional Flights Valued Using Consumer Surplus



LRMC is "Long Run Marginal Cost", defined as the cost of providing a flight i*n the absence of delay*

Figure 11 - NextGen's Impact on Supply and Demand Relationships for Air Transportation Services

Assuming a linear demand curve with a slope of -1, the value of additional flights is then given by the equation:

$$Value\ of\ \ Additional\ \ Flights = \frac{1}{2}(\Delta\ delay\ cost)\times(\Delta\ \ flights)$$

Valuing Reductions in the Number of Canceled Flights

Flight cancellations are costly to airlines and passengers. However, at some point it is preferable to cancel a flight rather than incur the even higher costs of excessive delays.

No generally accepted cost of cancellations is available for use in government cost-benefit studies, as there is with ADOC or PVT. However, several studies have investigated the issue, two of which provide the basis for this Business Case's treatment[18]. Based on these references,

[18] J. Xiong and M. Hansen, "Value of Flight Cancellation and Cancellation Decision Modeling", *Transportation Research Record*, Vol. 2106 (2009); National Center of Excellence for Aviation Operations Research, *Total Delay Impact Study* (2010), nextor.org.

aircraft operators assign a fixed cost of $4,977 per cancellation, while the cost to passengers is based on applying PVT values to an estimated average of 457 minutes of disrupted passenger delay per canceled flight[19]. Mathematically, these are calculated as follows:

$$Value\,of\ Reduced\ Cancellations(airlines) = (\Delta canceled\ \ flights) \times \left(\frac{\$4{,}977}{flight}\right)$$

$$Value\,of\ Reduced\ Cancellations(passengers) =$$

$$(\Delta canceled\ \ flights) \times \left(\frac{PVT}{minute}\right) \times \left(\frac{457\ minutes}{passenger}\right) \times \left(\frac{passengers}{flight}\right)$$

OPERATIONAL IMPROVEMENTS MODELED

A large portion of NextGen improvements to the NAS and capabilities listed in the Future of the NAS report have been modeled in SWAC and included in this Business Case. As mentioned earlier, not all improvements have been included due to current model limitations. Nearly 85 percent of the cumulative benefits through 2030 by value reported here are derived from SWAC outputs. Remaining benefits are based on FAA program office studies. Table 6 present the OIs and OI Increments currently modeled, and Table 7 presents the OIs and OI Increments, the benefits of which were furnished by FAA program office studies[20]. As the SWAC model continues to develop, it should capture an increasingly greater share of total benefits.

Table 6 - Operational Improvements Modeled in SWAC

Portfolio	Operational Improvement or Operational Improvement Increment
Surface	Remote Operations at Non-Towered Airports (102138-01)
	Surface Situational Awareness for Traffic Management (104209-17)
Time Based Flow Management	Interval Management-Space Cruise (102118-21)
	Implement TMA at Additional Airports (104115-12)
	Extended Metering (104120-11)
	Meet TBFM Constraints Using Required Time of Arrival (104120-22)
	Use RNAV Data to Calculate Trajectories Used to Conduct Time Based Metering Operations (104123-11)
	Ground-Based Interval Management-Spacing (104123-12)
	Time-Based Metering in the Terminal Environment (104128-24)

[19] This estimated value of passenger delay includes the average time lost due to having to re-book on a different flight.

[20] The numbers in parentheses are the identifiers for the operational improvements in the FAA's NAS Enterprise Architecture. (Federal Aviation Administration, *NAS Enterprise Architecture*, sep.faa.gov/architecture/main).

Improved Multiple Runway Operations	Wake Turbulence Mitigation for Departures (102140-01)
	Additional 7110.308 Airports (102141-11)
	Amend Independent Runway Separation Standards in Order 7110.65 (including Blunder Model Analysis) (102141-13)
	Amend Dependent Runway Separation Standards in Order 7110.65 (102141-14)
	Enable Additional Approach Operations for New Independent Runway Separation Standards (102141-15)
	Wake Turbulence Mitigation for Arrivals - Procedures for Heavy/B757 Aircraft (102144-11)
	Wake Turbulence Mitigation for Arrivals - System for Closely Spaced Parallel Runways Spaced Less than 2,500 Feet Apart (102144-21)
	Paired Approaches for Runways Spaced Less than 2,500 Feet (CAT I) (102157-21)
	Paired Approaches for Runways Spaced Less than 2,500 Feet (CAT II) (102157-22)
Improved Approaches and Low-Visibility Operations	Initial Tailored Arrivals (104124-11)
	OPDs Using RNAV Standard Terminal Arrival Routes (104124-12)
	Enhanced Flight Vision Systems for Approach (107117-11)
	Synthetic Vision Guidance Systems for Approach (107117-12)
	Enhanced Flight Vision Systems for Landing (107117-13)
Performance-Based Navigation	Integrated Arrival and Departure Management Services: Airspace Enhancements (104122-23)
	RNAV SIDs and STARs at Single Sites (107103-13)
	Optimization of Airspace and Procedures in the Metroplex (108209-12)
	Transition to PBN Routing for Cruise Operations (108209-14)
Separation Management	Enhanced Oceanic Climb / Descent Procedure via Automatic Detection Surveillance - Contract Automation (102108-12)
	Wake Turbulence Mitigations for En Route Controllers (102117-21)
	Vertical Conformance Verification Entry (102137-28)
	En Route Conformance Monitor for PBN Routes (102137-34)
	Interval Management – Defined Interval (IM-DI) (102148-01)
	Wake Recategorization Phase 1 – Aircraft Re-Categorization (102154-11)
	Wake Recategorization Phase 2 – Static Pair-wise Wake Separation Standards (102154-21)

	Approval of User Requests and Resolving Conflicts with Efficient Maneuvers in En Route Airspace (104104-01)
	Reduced Controller Coordination for Strategic Resolution Maneuver Implementation (104104-04)
	Approval of User Requests and Resolving Conflicts with Multiple Maneuvers in En Route Airspace Phase 2 (104127-22)
NAS Infrastructure	Current Oceanic Separation (102105)
	Space-Based ADS-B (102158-01)
	Initial En Route Data Communication Services (102158-01)
	Full En Route Data Communications (102158-02)

Table 7 - Operational Improvements Captured from Other Sources

Portfolio	Operational Improvement or Operational Improvement Increment
Collaborative Air Traffic Management	Route Availability Planning (101102-12)
	Airborne Rerouting (105208-21)
Improved Surface Operations	Cockpit Display of Traffic Information with Traffic Information Service–Broadcast and ADS-B for Surface (103208-12)
	Revised Departure Clearance via Data Comm (104208-12)
Time Based Flow Management	Integrated Departure/Arrival Capacity (104117-11)
Performance Based Navigation	Advanced and Efficient RNP (Established on RNP) (108209-20)
On-Demand NAS Information	Traffic Situational Awareness with Alerts (103209-01)
	Provide NAS Status via Digital Notices to Airmen for Flight Operation Center (FOC)/Airline Operation Centers (AOC) (103305-13)
	Improve Special Activity Airspace-Based Flow Predictions (105104-21)
NAS Infrastructure	Common Support Services – Weather (103305-25)

APPENDIX B: COST METHODOLOGY

Implementing NextGen will require significant investments from the FAA and — to a lesser extent — from aircraft operators to fund the deployment of improvements. Certain capabilities and operational improvements require operators to update avionics to reap the benefits, but currently, only ADS-B Out is mandatory equipage[21]. This chapter discusses the projected costs of mid-term NextGen improvements for the FAA and aircraft operators, along with the methodology used to derive them.

COSTS TO THE GOVERNMENT

Facilities and Equipment Costs

Cost estimates for the FAA to develop and deploy NextGen improvements are derived from internal agency budget estimates. The FAA's Facilities and Equipment (F&E) budget request covers the capital costs to develop improvements — primarily the development of infrastructure, hardware and software. The F&E budget request is based on the Capital Investment Plan (CIP) for FY 2016–2020[22]. The budget estimates in the CIP come from detailed cost estimates developed by FAA program offices. The CIP provides the basis of the F&E cost estimates, which have been submitted to OMB and to Congress.

For many NextGen programs, the published five-year time horizon of the CIP does not cover their entire development period. In these cases, the published CIP must be supplemented with cost estimates provided by the program offices or the NAS Systems Engineering and Integration Office.

Since NextGen will be completed by FY 2025, the F&E budget reflects a tapering off of NextGen activities in FY 2024–2025. The budgets for FY 2026–2030 cover only ongoing ADS-B subscription fees and expected program technology refreshes, such as replacing infrastructure and hardware that have reached the end of their service lives. In addition, the budgets for FY 2026–2027 are supplemented with contingency funds to ensure the completion of late NextGen improvements.

Table 8 shows the NextGen F&E budget according to the structure of the NextGen Implementation Plan (NGIP)[23]. It includes all NextGen programs and portfolios, including programs whose costs are not covered by the NextGen F&E portion of the CIP. New in this version of the Business Case are two cost categories not included in the NGIP: NextGen Support Portfolio and Cross-Agency NextGen Management[24]. NextGen Support Portfolio covers

[21] Federal Regulation 14 CFR 91.225 and 14 CFR 91.227 (May 2010), http://go.usa.gov/x3FhY.

[22] Federal Aviation Administration, Capital Investment Plan FY 2016–2020, http://go.usa.gov/x3FhQ.

[23] Federal Aviation Administration, *NextGen Implementation Plan*, p. 2 (August 2014), http://go.usa.gov/x3Fhe.

[24] NextGen Support Portfolio is made up of a combination of CIP budget line item numbers while the Cross-Agency NextGen Management CIP budget line item number is 4A10.

NextGen testing and operational assessment costs as well as overhead and indirect costs associated with NextGen. Cross-Agency NextGen Management covers managerial oversight of NextGen progress to ensure development coordination.

Table 8 - NextGen Facilities & Equipment Budget Programs and Portfolios

NextGen Programs	Automatic Dependent Surveillance–Broadcast (ADS-B)
	Data Communications (Data Comm)
	En Route Automation Modernization (ERAM)*
	Terminal Automation Modernization and Replacement (TAMR)*
	NAS Voice System (NVS)
	System Wide Information Management (SWIM)
NextGen Portfolios	Improved Surface Operations
	Improved Approaches and Low-Visibility Operations
	Improved Multiple Runway Operations (IMRO)
	Performance Based Navigation (PBN)
	Time Based Flow Management (TBFM)
	Collaborative Air Traffic Management
	Separation Management
	On-Demand NAS Information
	Environment and Energy
	System Safety Management
	NAS Infrastructure
Other NextGen Activities	NextGen Support Portfolio
	Cross-Agency NextGen Management

* ERAM and TAMR base programs are not budgeted as NextGen investments because they are not delivering transformational capabilities. Follow-on work that provides additional capabilities may be budgeted as NextGen.

Research and Development Costs

The FAA's 2015 National Aviation Research Plan details NextGen R&D funding needs for the years 2015–2020[25]. As with the CIP, it is necessary to look beyond this horizon to accurately assess the cost of NextGen R&D. Unlike FAA capital programs, the allocation of these R&D funds to NextGen is difficult to accurately predict beyond a few years out. Along with the pre-implementation programs, R&D funding used on improvements is assumed to hold steady

[25] Federal Aviation Administration, *2013 National Aviation Research Plan*, http://go.usa.gov/x3Fzx.

through FY 2022, after which R&D funding is assumed to reduce as the implementation of new NextGen improvements concludes by FY 2025.

Operations Costs

NextGen improvements entail not only an investment component but also ongoing costs for operations. Estimated operations costs are presented in business cases for individual programs as they seek approval to move forward. Operations costs are considered in the FAA's decision making whether to fund the investment. Operations costs associated with NextGen are not included in the capital budget but rather in the agency's overall operations account. For this reason, the operations component is listed separately.

Where possible, operations costs were taken from the approved business cases of NextGen programs. For capital programs whose business cases have not yet been approved by the Joint Resources Council, the annual operations cost is estimated as a percentage of the total F&E investment. This estimate credibly approximates actual operations costs based on historical data.

Figure 12 shows the total estimated FAA cost for NextGen programs, broken out by F&E, R&D and operations.

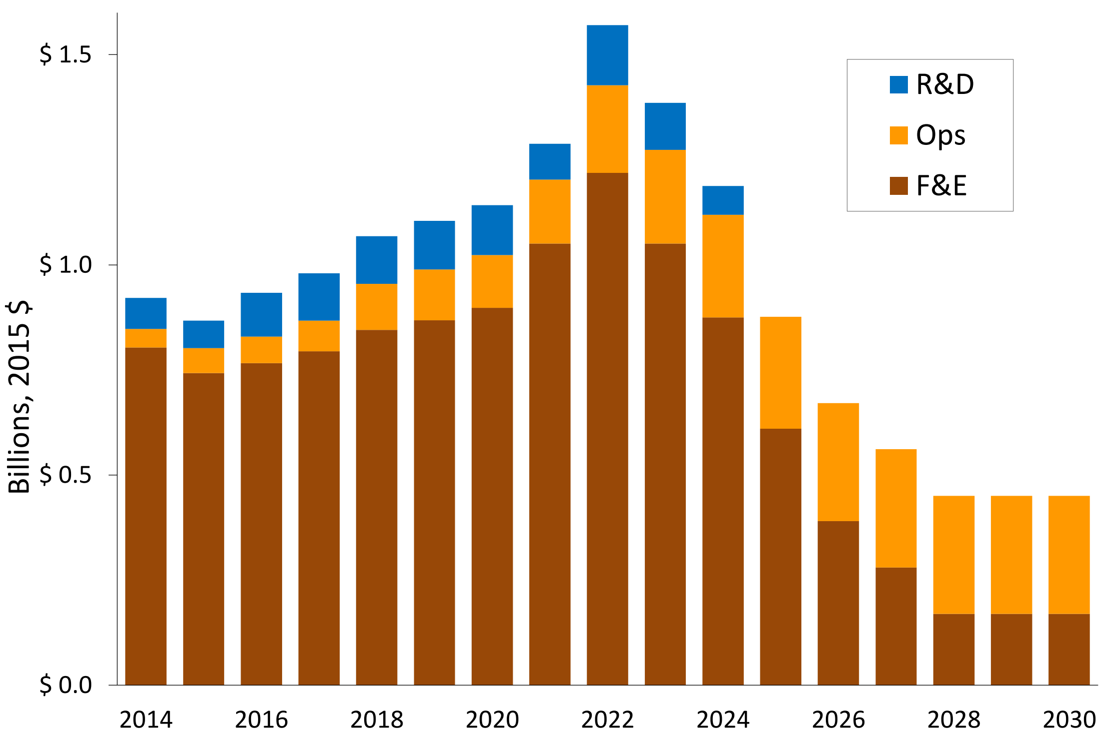


Figure 12 - Annual FAA Costs for NextGen Mid-Term Capabilities

COSTS TO AIRCRAFT OPERATORS

As stated earlier, the FAA is improving the performance and reliability of the NAS by investing in NextGen. But to take full advantage of NextGen's capabilities, aircraft will need new avionics. This cost will be borne by the aircraft operators.[26]

Commercial Aviation

*avionics*Coster, MITRE's new avionics costing model, projects costs to equip the current and future fleets of commercial aircraft with NextGen capabilities through 2030. *avionics*Coster only estimates costs for the U.S. air carrier fleet (those operating under 14 CFR Part 121). *avionics*Coster examines equipage for the current fleet, as defined by the FAA registry (last updated on July 2014), and for the forecasted aircraft yet to be delivered. The forecast fleet is determined using MITRE's *fleet*Forecaster tool, last updated in January 2014.

The benefits reported throughout this Business Case assume a certain equipage schedule for the commercial fleet. Generally, aircraft operators are not required to equip at these levels. Rather, this constitutes an expected level of equipage. For consistency with the benefit estimates, the cost estimates for avionics are based on this expected level, as shown in Table 9.

Table 9 - Projected Applicability by NextGen Capability

NextGen Segment Implementation Plan Enablers	NextGen Baselined Improvements	NextGen Anticipated Improvements	Target Equipage Level in 2030
RNAV 1	✓	✓	100%
RNAV 2	✓	✓	100%
RNP 1 with Curved Path	✓	✓	100%
Vertical Navigation	✓	✓	100%
Localizer Performance with Vertical Guidance	✓	✓	100%
RNP AR	✓	✓	63%
ADS-B Out[†]	✓	✓	100%
ADS-B In	N/A	✓	74%
FANS 1A+ (Very High Frequency Data Link (VDL) Mode 2)	✓	✓	55%

[†] FAA has mandated that aircraft operating in most controlled airspace equip with ADS-B Out by January 1, 2020.

[26] The estimated retrofit costs include direct installation. They do not include the opportunity cost of taking an aircraft out of service or ancillary costs, such as training.

The *avionics*Coster model applies economies of scale when feasible. Cost discounts are expected to reflect an operator's fleet size. Total equipage costs are determined either by summing up the individual components and installation costs or by aggregating cost for packages or suites of avionics and appropriate installation costs. Table 9 highlights the capability enabled by multiple avionics components for the baselined improvements and anticipated improvements cases. Unlike previous versions of this Business Case, avionics installation costs are considered on a per-suite basis rather than per-capability. The installation of individual avionics components can enable multiple capabilities due to shared functions for multiple systems.

Commercial aircraft not equipped with NextGen avionics will require retrofit. Retrofit cost estimates are provided by either a combination of manufacturers, suppliers and installers, or estimated by MITRE subject matter experts. The values can be actual retrofit costs for existing capabilities or estimated costs for new capabilities.

New aircraft are eligible for either forward fit "option" or forward fit "standard" equipage. Forward fit option includes the aircraft manufacturer's estimated price to include the capability option. Capabilities that come standard on new aircraft incur no additional cost. Forward fit cost estimates consider the necessary equipage to use NextGen capabilities based on historical avionics purchase patterns. This Business Case assumes the ADS-B Out equipage mandate of January 1, 2020 will be observed. Assuming operators will elect to keep their new fleets' avionics updated, a retrofit schedule for existing aircraft and a forward fit schedule for new aircraft has been created. MITRE's *fleet*Forecaster tool also considers fleet retirement schedules; aircraft retiring prior to an assigned equipage date are not included in the final equipage cost calculations.

MITRE provided estimates of current levels of avionics equipage. Combining current equipage levels with target future equipage levels and applying unit cost estimates, results in the total required cost of avionics investment, shown in Figure 13.

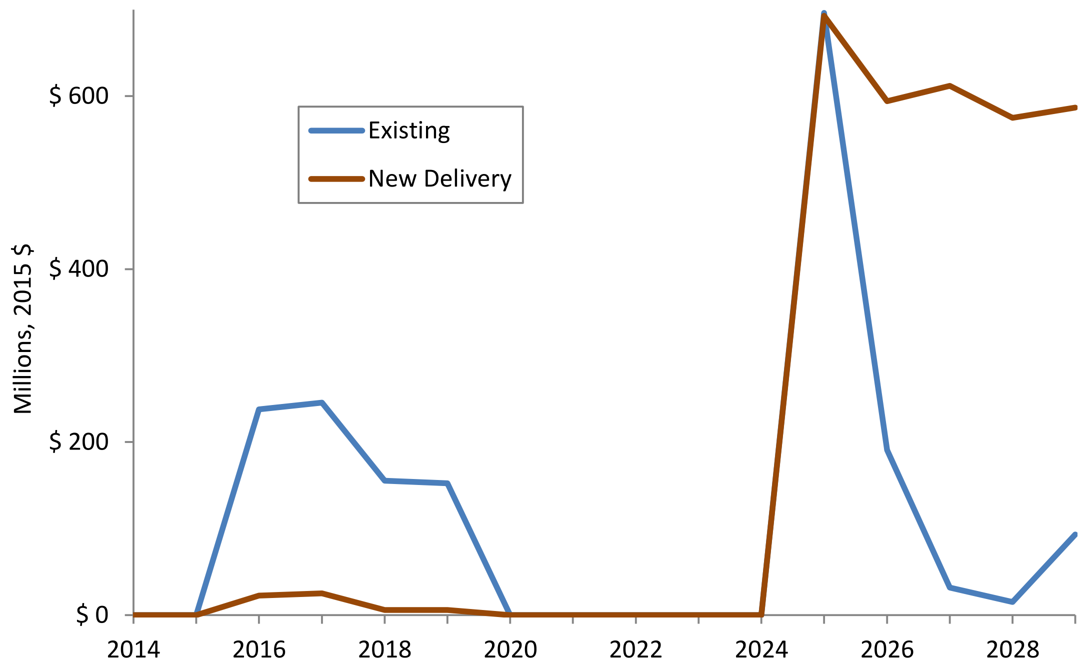


Figure 13 - Estimated Annual Operator Investment in NextGen Avionics, Retrofit vs. Forward Fit

No estimated costs are available for 2020–2024 because it was assumed a five-year retrofit/forward fit plan to have the commercial fleet equipped by 2030. This resulted in retrofits beginning in 2025. Costs prior to 2020 were from aircraft retrofitting for ADS-B Out.

Estimating the total cost to equip the fleet is difficult. Not only are the costs to equip highly variable by aircraft type and individual airframe, costs can also vary depending on whether avionics are installed separately or combined.

General Aviation

The equipage estimates for general aviation are based on classifying all such aircraft into two groups: high-end and piston aircraft. High-end general aviation aircraft is further broken out into jets and turboprops.

Table 10 below shows the equipage packages and unit costs assumed for general aviation aircraft. The unit cost estimates were derived from work done by MITRE in support of the RTCA NextGen Mid-Term Implementation Task Force[27]. Table 11 shows the quantities of general aviation aircraft expected to receive specified equipment packages. Table 12 is a summary of estimated commercial and general aviation avionics equipage costs.

Cost estimates for equipping general aviation aircraft have not changed from the 2014 Business Case for NextGen, excepting inflation.

[27] RTCA, NextGen Mid-Term Implementation Task Force Report (2009). Avionics cost estimates provided by the MITRE Corporation as supporting information.

Table 10 - Unit Cost by General Aviation Aircraft Type

Thousands, 2015 $	Data Communications (FANS 1/A+)		ADS-B Out		ADS-B In (CDTI)		RNP 0.3 with RF Legs	
	Retrofit	Forward Fit	Retrofit	Forward Fit	Retrofit	Forward Fit	Retrofit	Forward Fit
Turboprops	$82.3	$41.2	$15.4	$10.3	$30.9	$30.9	$267.5	$133.8
Jets	$82.3	$41.2	$15.4	$10.3	$30.9	$30.9	$267.5	$133.8
Piston	N/A	N/A	$14.4	$8.2	$30.9	$30.9	N/A	N/A

Table 11 - Quantities of Avionics Installations Performed by General Aviation Aircraft Type

	Data Communications (FANS 1/A+)		ADS-B Out		ADS-B In (CDTI)		RNP 0.3 with RF Legs	
	Retrofit	Forward Fit	Retrofit	Forward Fit	Retrofit	Forward Fit	Retrofit	Forward Fit
Turboprops	N/A	N/A	10,360	2,920	1,243	2,920	73	1,460
Jets	N/A	N/A	16,325	12,270	1,959	12,270	920	6,135
Piston	N/A	N/A	165,980	8,845	132,780	8,845	N/A	N/A

Table 12 - Estimated Avionics Equipage Costs

Billions, 2015 $	Baselined Improvements	Anticipated Improvements	**Total Improvements**
Commercial	$4.5	$0.8	**$5.3**
General Aviation	$4.6	$ 5.2	**$9.8**
Jet, Turboprop	$2.2	$0.6	**$2.8**
Piston	$2.5	$4.6	**$7.1**
Total	**$9.1**	**$6.0**	**$15.1**

APPENDIX C: CHANGES IN BENEFIT ESTIMATES SINCE LAST YEAR

WHY THE BUSINESS CASE IS UPDATED ANNUALLY AND WHY THE NUMBERS CHANGE

The FAA's goal is to provide the latest and best estimates of NextGen costs and benefits. Unfortunately, it reflects a view that is incomplete and evolving.

NextGen is the umbrella program the FAA uses to manage the modernization of the NAS. Individual NextGen improvement start dates, work duration and deployment schedules vary greatly from case to case. As such, the components of NextGen at any given time are in various stages of maturity. For implemented and baselined improvements, the costs, benefits and schedules are well-established because of their approved business cases of associated programs. For implemented improvements, some of these have been realized. However, anticipated improvements do not yet have approved business cases. With each year of maturation, this Business Case incorporates a greater amount of information and more accurate NextGen costs and benefits.

In addition to program plans, crucial factors that influence the cost and benefit estimates are subject to change. The principal changes are:

- Program schedules
- FAA traffic forecast
- Improvements to the FAA's simulation model (SWAC)

To ensure the cost and benefit estimates are current, the most up-to-date information is used to revise them annually. The following is a summary of the major changes since the 2014 Business Case, along with a summary of previous estimates for the past several years.

CHANGES TO PROGRAM SCHEDULES

As noted earlier, NextGen improvements require years of sustained development work in order to be deployed. Program schedules can and have slipped because of a combination of factors including funding shortfalls. Recently, actual funding levels have been less than expected when compared to the CIP from the previous year.

Because this Business Case only considers benefits deployed by 2030, schedule delays reduce the timeframe in which improvements can deliver benefits. The exact impact on future benefits of these delays cannot be precisely quantified. However, given the benefit-cost ratios in the Economic Analysis section on pages 17–21, every dollar invested results in multiple dollars of realized benefits.

CHANGES IN THE FAA'S TRAFFIC FORECAST

Instead of using static traffic data for benefits projections of present and future improvements, SWAC uses traffic projections from the FAA's Terminal Area Forecast (TAF). The TAF is an annual report that projects air traffic at all U.S. airports. Integrating TAF projections into SWAC modeling yields benefits based on the best future traffic estimates available.

The TAF has predicted traffic increases at the Core 30 airports since 2000. However, actual traffic has consistently been lower than the last several TAF projections. This shortfall is routinely visible even in the first projected year. Figure 14 compares the current traffic forecast for the Core 30 airports used in this analysis with the forecast used in the previous edition of this document[28]. The forecast for the Core 30 airports is 3.6 percent lower in 2030 than that used for previous results. Traffic demand tends to have a nonlinear effect on delay and benefits of efforts to mitigate delay. Thus the NextGen benefits would be expected to decrease by more than the decrease in forecast traffic.

The current TAF also projects substantial traffic growth in Boston, Honolulu, Los Angeles, Miami and Seattle. As congestion grows at these airports, NextGen benefits that mitigate delays and reduce fuel burn are expected to grow as well.

[28] Federal Aviation Administration, *Terminal Area Forecast, Fiscal Years 2013–2040*, see footnote 9 on page 30; Federal Aviation Administration, Terminal Area Forecast, Fiscal Years 2012–2040 (2013), aspm.faa.gov/main/taf.asp.

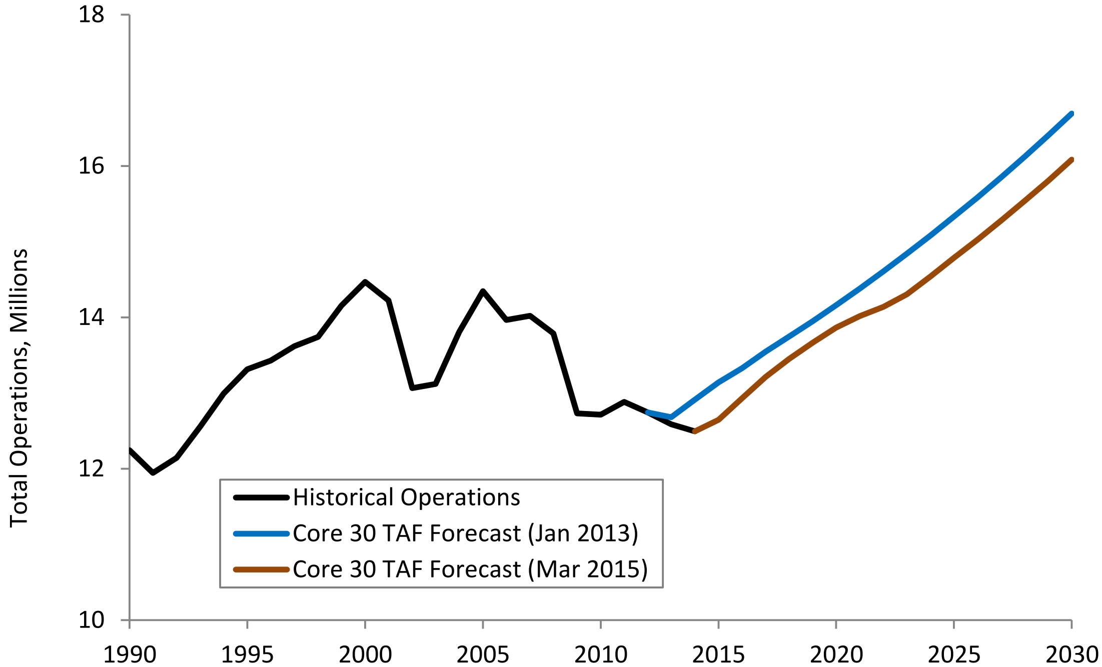


Figure 14 - Total Operations: Historical Operations (1990–2014), TAF January 2013 Forecast (2012–2030) and TAF March 2015 Forecast (2014–2030)

IMPROVEMENTS IN THE FAA'S SIMULATION MODEL

As with other aspects of NextGen benefits projections, the FAA's SWAC simulation model continues to improve. It now examines more variables and handles situations with greater sophistication and completeness than it did last year.

Expected Departure Clearance Times (EDCTs) are a case in point. In prior years, calculated EDCT delays were solely attributed to the arrival airport in the form of a Ground Delay Program (GDP). In the current SWAC model, EDCT delays can also be attributed to en route constraints in the form of an Airspace Flow Program (AFP). Both GDPs and AFPs estimate airborne delay and move it to the ground at the departure airport. Though ground delays are less costly than airborne delays, an increase in ground delays can lead to an increase in cancellations. The 2015 SWAC model moves more delays to the ground in the base case; hence the base case includes more cancellations than in the 2014 model. With NextGen improvements, more cancellations are avoided than with the previous model.

SWAC also now considers dynamic rerouting of flights based on forecast weather conditions. This may lead to increased demand for airspace near the inclement weather, which can increase the need for AFPs as previously discussed.

Also improved in the current SWAC modeling is the capture of delay costs resulting from congestion at the arrival airport. Aircraft awaiting arrival clearance not only burn additional fuel and incur greater delays, they also create sector backups. These, in turn, create second-order delay effects that are now being captured.

In total, the 2015 SWAC model now handles delays and cancellations more capably, which increases NextGen benefits as shown in Table 13. Assuming all factors remain equal and independent of SWAC model changes, the minor adjustments to program schedules and changes to the TAF would lower NextGen benefits slightly.

Lastly, SWAC-modeled benefits are supplanting some benefits that were provided by previously mentioned FAA program office studies. They account for a small portion of all NextGen benefits. When SWAC modeling is unable to derive the same type of improvement benefit, the benefit from FAA program office studies are used. Lately, though, SWAC modeling has calculated improvement benefits previously reported by the program office studies. In that case, the SWAC-modeled benefits are used. One example is benefits from Data Comm's Departure Clearance Service, now captured in SWAC.

CHANGES TO BENEFIT ESTIMATES OVER TIME

Tables 13 and 14 show the progression of benefit and cost estimates compared to previous versions of this Business Case. The year-to-year changes are driven by changes in program schedule, TAF and the modeling improvements described above. Overall NextGen benefits in the 2015 have increased due to the improvements in how SWAC models congestion.

Table 13 - Comparison of Annual Business Case Benefit Estimates of Future Improvements Through 2030

	Year of Business Case (Base Case vs. NextGen Case)			
	2012 (Billions, 2011 $) (2011–2030)	2013 (Billions, 2012 $) (2012–2030)	2014 (Billions, 2013 $) (2013–2030)	2015 (Billions, 2015 $) (2015–2030)
Avoided Delay	$76.9	$154.4	$99.6	$108.1
Reduced Flight Time	$1.7	$5.9	$4.6	$0.4
Fewer Flight Cancellations	$9.6	$3.4	$9.0	$25.3
Reduced CO_2	$1.1	$0.4	$0.4	$0.2
Other Benefits not Modeled in SWAC‡	$16.6	$17.7	$18.9	$13.4
Total	**$105.9**	**$181.8**	**$132.5**	**$147.4**

‡ Safety, FAA cost savings, etc.

Table 14 - Comparison of Annual Business Case Costs Through 2030

	Year of Business Case			
Billions, 2015 $	2012 (2007–2030)	2013 (2007–2030)	2014 (2013–2030)	2015 (2014–2030)
FAA Capital Cost (F&E)	$10.5	$11.5	$9.2	$11.7
FAA R&D Directly for NextGen	$1.0§	$1.1**	$0.7**	$1.1
FAA Ongoing Operations (est.)	$7.5	$7.8	$4.1	$2.9
Aircraft Operators' Cost to Equip	$20.0	$20.0	$15.9	$14.7
Total	**$39.0**	**$40.4**	**$29.9**	**$31.1**

§ 2007–2018
** 2007–2019

This Business Case has been published only since 2012. However, the same modeling methodology has been used to generate shorter-term estimates reported in the NGIP, which has a longer history. While benefits are no longer included in the NGIP, Table 15 shows NextGen benefits from prior NGIP estimates and the NextGen benefits had they been published for 2014 and 2015.

Table 15 - Summary of NextGen Benefits

	NextGen Implementation Plan					
	2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Starting Forecast Year in SWAC	2009	2010	2011	2012	2013	2014
Total Benefits through 2020 (Billions, 2015 $)	$22	$23	$24	$38	$18	$14.9
Total Fuel Savings through 2020 (Billions of Gallons)	1.4	1.4	1.4	1.6	0.8	0.42
Delay reduction in FY 2020	-21%	-35%	-38%	-41%	-11%	-11%

** The 2010 NGIP used 2018 as its forecast horizon, not 2020.

ACRONYMS, INITIALISMS AND ABBREVIATIONS

4-D	Four Dimensional
ACM	Adjacent Center Metering
ADOC	Aircraft Direct Operating Cost
ADS-B	Automatic Dependent Surveillance–Broadcast
AFP	Airspace Flow Program
AOC	Airline Operation Center
ASDE-X	Airport Surface Detection Equipment–Model X
ATL	Hartsfield-Jackson Atlanta International Airport
BADA	Base of Aircraft Data
CAT	Category
CATM	Collaborative Air Traffic Management
CDTI	Cockpit Display of Traffic Information
CIP	Capital Investment Plan
CO_2	Carbon Dioxide
CRDA	Converging Runway Display Aid
CSPR	Closely Spaced Parallel Runways
CVG	Cincinnati/Northern Kentucky International Airport
Data Comm	Data Communications
EDCT	Expected Departure Clearance Time
ELSO	Equivalent Lateral Spacing Operations
ELVO	Expanded Low-Visibility Operations
ERAM	En Route Automation Modernization
F&E	Facilities and Equipment
FAA	Federal Aviation Administration
FANS	Future Air Navigation System

FY	Fiscal Year
FOC	Flight Operation Center
GDP	Ground Delay Program
IFR	Instrument Flight Rules
IMRO	Improved Multiple Runway Operations
MEM	Memphis International Airport
Metroplex	Metroplex Airspace Redesign
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NextGen	Next Generation Air Transportation System
NGIP	NextGen Implementation Plan
NPV	Net Present Value
NVS	NAS Voice System
NWP	NextGen Weather Processor
OI	Operational Improvement
OMB	Office of Management and Budget
OPD	Optimized Profile Descent
PBN	Performance Based Navigation
PVT	Passenger Value of Time
R&D	Research and Development
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP AR	Required Navigation Performance Authorization Required
RTCA	Radio Technical Commission for Aeronautics
RVR	Runway Visual Range
SCC	Social Cost of Carbon

SDF	Louisville International Airport – Standiford Field
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival
STARS	Standard Terminal Automation Replacement System
SWAC	System Wide Analysis Capability
SWIM	System Wide Information Management
TA	Tailored Arrival
TAF	Terminal Area Forecast
TAMR	Terminal Automation Modernization and Replacement
TBFM	Time Based Flow Management
TFDM	Terminal Flight Data Manager
TMA	Traffic Management Advisor
VDL	Very High Frequency Data Link
Wake Recat	Wake Recategorization

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