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Assessment and Alignment of NASA ATM-Airspace Project with NextGen R&D Needs

Michael Greene, George Price, Robert Rosen, and James Cistone
Crowne Consulting, Inc.
Washington, D.C.

July 2008

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SUMMARY

This report describes the alignment of activities of the ATM-Airspace Project, one of two elements of the NASA Airspace Systems Program, with the R&D needs established in the Next Generation Air Transportation System (NextGen) R&D Plan and the NextGen Integrated Work Plan (IWP).

The research focus areas (RFAs) of the ATM-Airspace Project were analyzed with respect to the NextGen R&D needs. Based on this analysis, this report identifies the NextGen R&D needs that are supported by each RFA, as well as the linkage between the milestones in each RFA and the R&D needs. The RFAs that constitute the ATM-Airspace Project are:

- Trajectory Prediction and Uncertainty
- Performance-Based Services
- Dynamic Airspace Configuration
- Traffic Flow Management
- Separation Assurance
- Super-Density Operations
- System-Level Design, Analysis, and Simulation Tools

It was found that there is close alignment between the project's research activities and the NextGen R&D needs. In fact, all of the project's 118 milestones are shown to be directly linked to NextGen R&D needs. Furthermore, by virtue of the fundamental nature of the NASA research, all but two of the milestones support multiple NextGen needs, demonstrating the project's robust applicability.

Analysis of the results shows that the ATM-Airspace Project directly supports 54 R&D needs and 48 operational improvements (OIs) identified in the IWP. Within the IWP functional area most closely related to air traffic issues, Trajectory-Based and Performance-Based Operations and Support, the project directly supports 45 R&D needs and 42 associated OIs. In addition, the seven RFAs provide broad support for the Weather Information Services, Safety Management, and Environmental Management Framework functional areas.

This report also includes an appendix summarizing four key documents issued by the NextGen Joint Planning and Development Office: the Integrated National Plan for the Next Generation Air Transportation System; the Concept of Operations for the Next Generation Air Transportation System, Version 2.0; the Research and Development Plan for the Next Generation Air Transportation System, FY 2009–FY 2013; and the Integrated Work Plan for the Next Generation Air Transportation System, Version 0.2.

1. INTRODUCTION

1.1 Overview

This report describes the alignment of the NextGen Air Traffic Management (ATM) - Airspace Project, one of two elements of the NASA Airspace System Program, with the research needed to support development of the Next Generation Air Transportation System (NextGen).

Since it was chartered by the Congress in 2003 to plan, develop, and implement NextGen, the Joint Planning and Development Office (JPDO) has created a set of governing documents that define NextGen, including its operational concept and the range of required technologies. This information is being used by the JPDO partner agencies, including NASA, to define and validate supporting programs.

NASA's projects within the Airspace Systems Program have provided vital research and technology to the FAA in the past. With the advent of NextGen, these projects have been realigned to focus on NextGen needs. The realignment is intended to enhance NASA's contribution to the success of NextGen, establish a focus to formulate and prioritize research tasks, and provide a transition path for NextGen partners to implement the results of NASA research. From the JPDO point of view, this perspective facilitates planning for technology transition and can help to identify potentially unmet needs and their impacts on the success of NextGen.

To ensure that the ATM-Airspace Project maximizes its contribution to NextGen through this alignment, it is necessary to elaborate in detail the linkages between project activities including milestones on the one hand and NextGen research and development (R&D) needs and related operational improvements on the other. The ATM-Airspace Project engaged Crown Consulting, Inc., to provide subject matter expertise and assist the project office in analyzing and documenting these relationships. The analysis reported here is based on specific R&D needs identified by the JPDO in its Research and Development Plan issued in 2007 and in the NextGen Integrated Work Plan issued in 2007 and updated since. These needs are linked to ATM-Airspace Project activities and milestones described in the ATM-Airspace Project Reference Material on the NASA Aeronautics Research Mission Directorate (ARMD) Web site.

The effort that resulted in this report considered the 167 R&D activities and 140 operational improvements identified in the JPDO documents and the 118 milestones in the 7 research focus areas (RFAs) of the ATM-Airspace Project.

The new information that this report provides is the assignment of NextGen R&D needs to ATM-Airspace Project RFAs, including for each RFA the association of project milestones with these R&D needs. Extensive material is available describing the Airspace Systems Program and the ATM-Airspace Project; this report excerpts much of that material to describe elements of the program and the project. In many cases the material is quoted directly with no changes and in others minor edits were made in the interest of clarity and conciseness. The primary sources for the NASA material are the descriptions of the program and project on the NASA ARMD Web site, the ATM-Airspace Project Draft Technical Integration Report dated August 26, 2007, and the ARMD on-line documents for the FY 2007 NASA Research Announcement Rounds 1, 2, and 3. Reference data for all of these documents appears in the bibliography (Appendix B). The source material used to describe NextGen comprises the JPDO documents listed in Appendix B.

The paragraphs immediately below briefly summarize the applicable NextGen and ATM-Airspace Project documents. More detailed descriptions of both sets of documents are presented in Appendix A and in Section 2, respectively. The versions used for this study were those in effect when the analyses were performed in early 2008; the publishing date of each document is shown in Appendix B.

1.2 Key NextGen Documents

Overview

Among the principal products of the JPDO are the documents that guide the planning and development of NextGen. Requirements and concepts flow from the highest level document, the Next Generation Air Transportation System Integrated Plan, referred to in this report as the National Plan, followed by the Concept of Operations, called the ConOps, and then the Research and Development Plan (R&D Plan) and the Integrated Work Plan (IWP), both of which specify the research and development needed to realize NextGen. Figure 1.2-1 provides a view of this hierarchy; the documents shown are described in Appendix A of this report and briefly summarized in the paragraphs below.

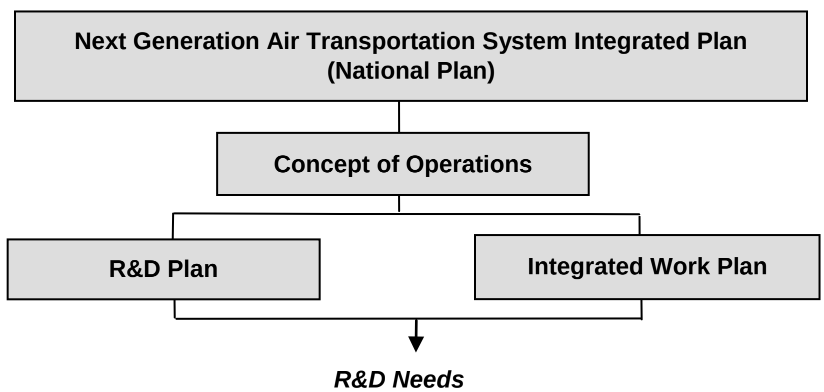


Figure 1.2-1 NextGen Document Hierarchy

National Plan

The National Plan, issued by the JPDO in 2004 in response to its chartering legislation, lays out a common vision, establishes benchmarks, and provides a structure for the JPDO to define and develop NextGen. It sets forth high-level goals and objectives and is the source document for all subsequent planning. The goals are described at the strategic level: retain U.S. leadership in aviation, protect the environment, ensure safety, secure the Nation, and ensure our national defense. Among these goals, and underlying the entire effort, is the need to put in place by 2025 a system scalable to accommodate up to three times the current demand on the aviation system.

ConOps

To turn these goals into a common vision of the future, the JPDO developed the NextGen Concept of Operations, or ConOps. This document describes how the 2025 system will operate from many points of view, such as the aircraft operators', the air navigation service provider's, and the security organization's. The ConOps embodies several new concepts and capabilities, such as Trajectory Based Operations, Performance Based Services, High Density Airports, and

Integrated Weather, which integrates real-time weather data into decisionmaking tools. The ConOps identifies research and policy issues that must be resolved to implement these and other new concepts.

R&D Plan

A further level of detail appears in the R&D Plan, organized into 12 R&D needs areas which address the research issues introduced in the ConOps. This plan was developed to serve as guidance for the JPDO partner agencies and other stakeholders. It defines high-level R&D milestones regarding policies, procedures, and technologies to achieve the capabilities in the ConOps. For each of the R&D needs areas, key NextGen challenges are described as a set of objectives, outcomes, and R&D needs. Each R&D need consists of a statement of what is needed, when it is needed, and which agencies will participate in its accomplishment. Most R&D needs encompass a broad range of activities; hence, many specific research initiatives may be required to support a particular R&D need. These R&D needs, as the final product of the flowdown, provide the information to guide NASA research and ascertain its relevance.

Integrated Work Plan

The final JPDO document is the Integrated Work Plan (IWP). It describes the long-term transition from the current air transportation system to the fully realized NextGen enterprise. It lays out NextGen research, policy, and implementation activities and their dependencies, and provides a collaborative planning and management tool for all of the mission partners. The IWP contains the full spectrum of work required by NextGen, and the R&D activities in the IWP correspond to the R&D needs in the R&D Plan. The IWP also shows the relationships among the R&D elements and other implementation activities. As the governing document, the IWP will be updated periodically. It is organized into the major functional areas of the NextGen enterprise, which were derived from the ConOps and the NextGen enterprise architecture. For each of these functional areas, the IWP describes a number of data elements, such as operational improvements, policy needs, and decision points, including the 167 R&D activities taken from the R&D needs in the R&D Plan.

1.3 ATM-Airspace Project

The NASA Airspace Systems Program (ASP) performs research on air traffic management (ATM) concepts, capabilities, and technologies for high-capacity, efficient, and safe airspace systems. This report addresses the ATM-Airspace Project, one of the two projects which constitute the program.

The ATM-Airspace Project includes research at all levels, from basic research in conjunction with NASA's university partners to integrated solutions with NextGen partners working at the systems level to explore and develop integrated research solutions that define and assess ground and air automation concepts and technologies necessary for NextGen. Commensurate with the lead times involved for the evolution of research to implementation, most of the research focuses on issues related to concepts planned for implementation from 2019 onward.

ATM-Airspace Project research activities are organized into groupings of like technical activities called research focus areas (RFAs). Four of these are related to specific air traffic management functions:

- Separation Assurance, which reduces capacity limitations arising from human-controlled separation assurance for transition and cruise airspace

- Airspace Super Density Operations, which reduces capacity limitations arising from human-controlled separation assurance for terminal airspace
- Dynamic Airspace Configuration, which strives to increase capacity through dynamic allocation of airspace structure and controller resources
- Traffic Flow Management, which allocates demand through control of departure times, route modification, adaptive speed control in the presence of uncertainty, and other techniques.

Supporting the functional thrusts of these RFAs are three supporting RFAs which cut across the functional RFAs:

- Trajectory Prediction, Synthesis, and Uncertainty, which develops trajectory predictions that are interoperable with aircraft flight management system (FMS) trajectory generations that use predictions of propagation and growth of uncertainty
- Performance Based Services, which explores the performance-enhancing effect of emerging airborne technologies on solutions to fundamental ATM problems
- System-Level Design Analysis and Simulation Tools, which develops system design and analysis tools to assess the functional and temporal distribution of work between automation and humans.

The project descriptions present specific milestones to be accomplished within each RFA, including a projected completion year, results to be accomplished, and metrics to measure them.

1.4 Alignment with NextGen

This report focuses on the alignment of the seven RFAs in the ATM-Airspace Project and their corresponding research milestones with the R&D needs from the NextGen R&D Plan (called R&D activities in the IWP). Alignment between the NASA program and NextGen in a broad sense is the subject of a White Paper on the NASA Aeronautics Web site titled "NASA & the Next Generation Air Transportation System (NextGen)." The paper discusses NASA's role in NextGen, how the NASA Aeronautics Research programs support NextGen R&D needs, and actions to enhance and maintain this alignment. It may be found at: http://www.aeronautics.nasa.gov/docs/nextgen_whitepaper_06_26_07.pdf.

Section 2 of this report describes in more detail the relationship between the ATM-Airspace Project activities and the R&D needs set forth in the NextGen R&D Plan and IWP. Because the RFAs represent logical groupings of research topics, while the IWP is organized according to functions to be performed in the operational system, the relationships between RFAs and the functional areas established in the IWP are broad and many-to-many rather than one-to-one. To definitively establish the alignment requires more detailed analysis. By examining the NASA work at the level of RFA milestones and comparing them to the NextGen R&D needs and the operational improvements supported by each R&D need, it is possible to better understand the relationship between the ATM-Airspace Project and NextGen. Analyzed at this level, it is seen that they are strongly aligned.

To define this alignment, Crown Consulting subject matter experts extracted the linkages between OIs and R&D needs from the IWP and then collaborated with members of the Airspace Systems Program and ATM-Airspace Project staffs to develop the linkages between project milestones in the ATM-Airspace Project Reference Material and NextGen R&D needs. Section 2 of this report further explains the methodology and describes the alignment for each RFA.

2. ATM-AIRSPACE PROJECT ALIGNMENT WITH NEXTGEN R&D NEEDS

2.1 Introduction

The NASA Aeronautics Research Mission Directorate (ARMD) is guided by three core principles: (1) mastery and intellectual stewardship of the core competencies of aeronautics for the Nation in all flight regimes, (2) focusing research on topics that are appropriate to NASA's unique capabilities, and (3) addressing the fundamental R&D needs of NextGen while working closely with its agency partners in the JPDO. In accordance with these principles, ARMD has established a balanced research portfolio that draws on its NASA-unique capabilities to address air traffic management, environmental, efficiency, and safety-related research challenges, all of which must be resolved to achieve the NextGen vision. ARMD research activities comprise three major programs: the Fundamental Aeronautics Program, the Airspace Systems Program, and the Aviation Safety Program; all three contribute directly to NextGen. Together, these programs address critical air traffic management, environmental, efficiency, and safety-related research challenges. The output of this focused commitment and investment includes advanced concepts, algorithms, tools, methods, technologies, and validation activities, all of which are critical to the success of NextGen.

The Airspace Systems Program addresses the R&D needs of NextGen by developing en route, transitional, terminal, and surface capabilities. It consists of two separate projects, ATM-Airspace and ATM-Airportal, which together conduct the long-term research needed to implement the NextGen vision. The ATM-Airspace Project develops and explores fundamental concepts and integrated solutions that address the optimal allocation of ground and air automation technologies necessary for NextGen. This project focuses NASA's technical expertise and facilities to address the question of where, when, how, and to what extent automation can be applied to moving aircraft safely and efficiently through the National Airspace System (NAS). The ATM-Airportal Project develops and validates algorithms, concepts, and technologies to increase throughput of the runway complex and achieve high efficiency in the use of airportal resources such as gates, taxiways, runways, and final approach airspace. NASA research in this project will lead to solutions that safely integrate surface and terminal area air traffic optimization tools and systems with 4D trajectory operations. Ultimately, the roles and responsibilities of humans and automation in the ATM system will be addressed by both projects. This document addresses the ATM-Airspace Project, with a focus on its alignment with the needs of NextGen.

2.2 ATM-Airspace Project Summary

The goal of the ATM-Airspace Project is to develop and explore concepts, capabilities, and integrated solutions that contribute fundamental research data and analyses needed for NextGen. Through analyses, prototyping, laboratory-based simulations, and, in special cases, flight evaluations, NASA together with the JPDO, industry, and academic partners will develop and promulgate knowledge to reduce the technical risk of NextGen.

Figure 2.2-1 depicts the decomposition levels of the ATM-Airspace Project, as portrayed in the on-line ATM-Airspace Project Reference Material. The project includes research at all levels of complexity, with NASA-sponsored academic and industrial research partners concentrating on foundational physics and modeling (Level 1 in Figure 2.2-1) and discipline-level capabilities (Level 2), and with NASA its JPDO partners addressing multidiscipline capabilities (Level 3) and interdisciplinary system design tasks (Level 4). The levels are a decomposition of the problem space which maps to the integrated solutions needed for NextGen at the top and the sciences, disciplines, and multidisciplinary research at the lower levels.

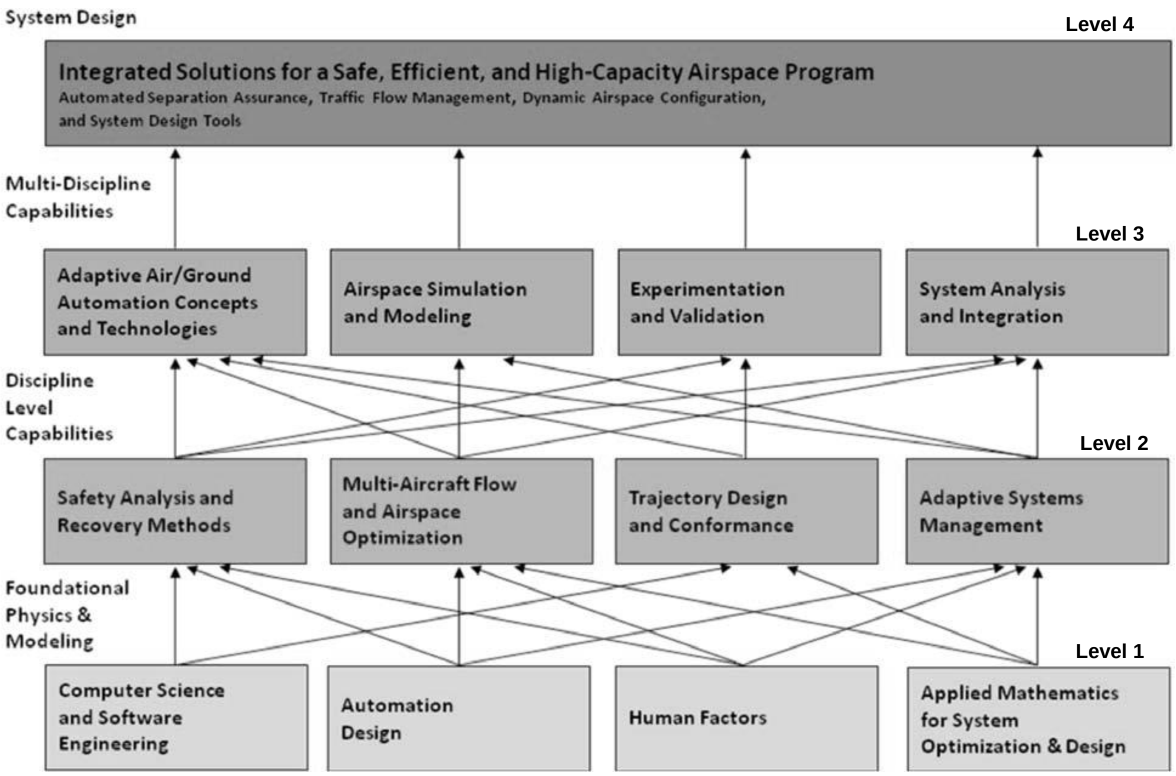


Figure 2.2-1 ATM-Airspace Project Decomposition Levels

Each of the seven research focus areas (RFAs) of the ATM-Airspace Project is a collection of research activities based on similar technical objectives and related areas of investigation. The ATM-Airspace Project RFAs are:

- Trajectory Prediction, Synthesis and Uncertainty (TPSU): Identifies and defines requirements for common capabilities and interoperability for trajectory prediction
- Performance Based Services (PBS): Develops classification systems and assesses performance capabilities needed to enable a shift towards air traffic services and operations requirements based on system performance capabilities rather than equipment type
- Dynamic Airspace Configuration (DAC): Works to increase capacity through strategic airspace organization and dynamic allocation of airspace structures and controller resources
- Traffic Flow Management (TFM): Identifies and resolves any imbalances in the demand and supply of NAS resources, such as airspace and runways
- Separation Assurance (SA): Identifies trajectory-based technologies and human/machine operating concepts that could support a substantial increase in capacity (e.g., 2X or 3X) with safety under nominal and failure-recovery operations, addressing airspace-user preference and with favorable cost/benefit ratios
- Airspace Super Density Operations (ASDO): Addresses airspace capacity barriers imposed by human workload and responsibility to enable high-efficiency trajectory-based operations that are robust to weather and other disturbances to satisfy NextGen demands

in super-dense and regional or metroplex airspace while minimizing environmental impact
- System Level Design, Analysis and Simulation Tools (SLDAST): Develops and applies system design and analysis methods and simulation tools to produce and assess integrated, comprehensive design alternatives.

Each RFA has a unique focus, but because much of the research is interrelated, many RFAs depend on concurrent research in the other areas. Additionally, research and development activities in the ATM-Airspace Project are tightly coupled with the work in the ATM-Airportal Project. While they each respond to unique constraints, the research efforts intended to address Airspace and Airportal issues often depend on one another.

2.3 Alignment of the ATM-Airspace Project with NextGen R&D Needs

Section 2.4 of this report summarizes the primary research activities of each RFA and describes how each RFA supports specific R&D needs for NextGen. The section for each RFA includes the following elements:

- Title and description – Identifies the RFA and provides a summary of its technical concentration. A major component of the ATM-Airspace Project acquisition strategy is the use of Research Opportunities in Aeronautics NASA Research Announcements (NRAs). The funding mechanisms used by NASA for research selected through an NRA are interagency transfers, grants, cooperative agreements, contracts, and NASA's internal processes for funding activities at its centers. A brief description of applicable NRAs is included in the section that addresses each RFA.

- Discussion of the supported R&D needs – This element introduces the primary NextGen R&D needs supported by the RFA. A table in each section presents the specific R&D needs in the NextGen R&D Plan that require the research of each RFA. It includes a description of the need, required completion date, and supported NextGen operational improvements described in the IWP. The NextGen R&D Plan specifies each of the R&D needs by alphanumeric reference. An "R" followed by a sequentially assigned number indicates an identified research need; "D" followed by a sequential number indicates an identified development requirement.

- Alignment of NASA milestones to R&D needs – The third element of each section shows the alignment between ATM-Airspace Project milestones for each RFA and specific NextGen R&D needs addressed by each milestone. This is presented at the milestone level because that provides the best description of what NASA is doing to support each R&D need. Analysis of the alignment at the milestone-to-R&D-need level illustrates complete alignment of the project with NextGen requirements. Milestones and R&D requirements are unlikely to remain completely static throughout the life of the program; some may change as a better understanding of the desired capability emerges from fundamental research informing more mature concepts. The ATM-Airspace Project expects to continually refine its project activities and milestones to maximize their responsiveness to NextGen needs.

To aid in understanding the subsequent discussion, it is necessary to introduce the NASA milestone numbering scheme. The numbering scheme includes the project name (AS, in this case), the level of the milestone in terms of NASA's four-level model, the RFA for that milestone, and a sequential number identifying each milestone. Table 2.3-I presents the numbering scheme for ATM-Airspace Project milestones.

Table 2.3-I ATM-Airspace Project Milestones Numbering Scheme

Project	Milestone Level	Research Focus Areas	Milestone Identifier
(AS) Airspace	(1) Foundational Sciences (2) Critical Disciplines (3) Inter-disciplinary Activities (4) System Design Information	(1) Trajectory Prediction Synthesis and Uncertainty (TPSU) (2) Performance-Based Services (PBS) (3) Dynamic Airspace Configuration (DAC) (4) Traffic Flow Management (TFM) (5) Separation Assurance (SA) (6) Super-Density Operations (SDO) (7) System-Level Design, Analysis, and Simulation Tools (SLDAST)	Sequence number identifying the milestone (01, 02, etc.)

For example, milestone AS.1.2.03 is the third Level 1 milestone in the PBS research focus area of the ATM-Airspace Project.

The analysis of the alignment between the ATM-Airspace Project and NextGen is based on matching elements of the project structure to elements of NextGen. While the ATM-Airspace Project is organized into RFAs, the NextGen IWP is organized into functional areas and subsidiary functional areas, designated as subareas in this report. Table 2.3-II lists the nine functional areas and the three subareas of the Trajectory-Based and Performance-Based Operations and Support functional area.

Table 2.3-II NextGen Functional Areas and Subareas

NextGen Functional Areas and Subareas
Trajectory-Based and Performance-Based Operations and Support • Air Navigation Operations (subarea) • Air Navigation Support (subarea) • Flight Operations and Support (subarea)
Airport Operations and Support
Weather Information Services
Safety Management
Layered Adaptive Security
Environmental Management Framework
Net-Centric Infrastructure Services
Positioning Navigation and Timing Services
Surveillance Services

The alignment between the NextGen and ATM-Airspace Project constructs is summarized in two tables which recur for each RFA. The first set of tables, titled “NextGen R&D Needs Addressed by (RFA name),” lists the R&D needs associated with each RFA and the operational improvements (OIs) supported by each of the R&D needs. The second set of tables lists the milestones for each RFA and the R&D needs supported by each of those milestones. The milestone set used for this analysis is taken from the ATM-Airspace Project Reference Material.

Figure 2.3-1 illustrates the information flow that leads to this analysis. Because the R&D needs represent the expression of technology needed to support NextGen, and because the project milestones are the most specific expression of technology accomplishments within the ATM-Airspace Project, the linkage between NextGen and the ATM-Airspace Project is most appropriately described at the level of R&D needs and project milestones.

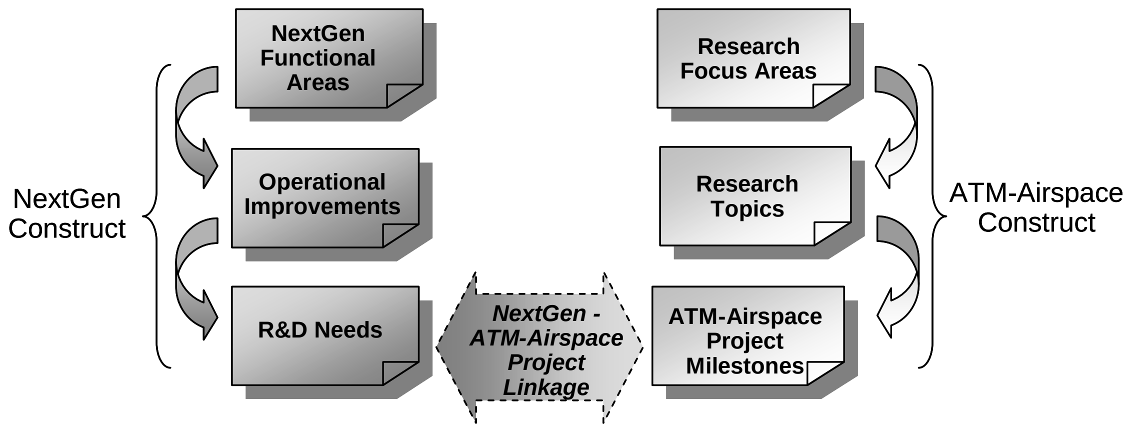


Figure 2.3-1 Constructs for NextGen and ATM-Airspace Project Alignment

The tables were developed in several steps. The first step was to associate the R&D needs in the NextGen R&D Plan with the appropriate RFAs of the ATM-Airspace Project. This step, conducted in collaboration with members of the Airspace Systems Program and ATM-Airspace Project staff, considered the activities and research topics of the RFAs and compared these with the R&D needs to determine which R&D need should be associated with each RFA. As stated in Section 1.3, because of the nature of the RFAs and the R&D needs, an R&D need may be associated with several RFAs, and vice versa.

The second step, accomplished by Crown Consulting subject matter experts, was to extract from the IWP the NextGen functional area(s) and operational improvements directly supported by each R&D need (identified in the tables as "Supported First-Tier OIs"). This resulted in the first set of tables.

In the third step, the project milestones were analyzed with respect to their stated objectives, timeframes, and outcomes and were compared to the specific requirements of each of the R&D needs. As a result of this analysis, each milestone was associated with the R&D needs that it supports. This activity, performed independently of the first two steps, was accomplished by program and project staff members, assisted by Crown Consulting subject matter experts, on the basis of practitioner knowledge, NASA program planning data, ongoing research activities, and NextGen objectives and technology needs. The results were then categorized by RFA to generate the second set of tables.

Because the two sets of tables were derived independently, the initial association of RFAs with R&D needs was not completely identical in both sets. Crown used the approach described in the preceding paragraph to reconcile the small number of differences that was found between the two sets.

To ensure compatibility with the IWP, all the R&D needs listed in the tables were compared to those assigned to NASA in the IWP. It was found that the RFAs and their milestones address all R&D needs within the scope of the ATM-Airspace Project.

2.4 Alignment Analysis by Research Focus Area

This section describes each of the RFAs of the ATM-Airspace Project and the alignment between their activities and R&D needs set forth in the NextGen IWP.

2.4.1 Trajectory, Prediction, Synthesis and Uncertainty (TPSU)

TPSU Description

TPSU identifies and defines the requirements for common capabilities and interoperability for trajectory prediction (TP). This includes the requirement to: (1) develop new TP algorithms that meet the defined requirements; (2) validate trajectory prediction accuracy; (3) identify, quantify, and model sources of uncertainty in TP; and (4) improve aircraft performance modeling.

The two principal thrusts of TPSU research to satisfy these requirements are (a) fundamental trajectory modeling and estimating, and (b) accommodating trajectory prediction uncertainty. TPSU trajectory modeling and prediction research will provide common trajectory prediction algorithms and components as well as trajectory modeling and synthesis technologies needed to support cutting-edge research concepts. Multiple sources drive uncertainty related to trajectory prediction. An automation system must have detailed knowledge of the aircraft's performance characteristics, procedures, and pilot intent to accurately predict a trajectory. The modeling of inaccuracies must consider many factors, including environmental factors (e.g., wind, convective weather systems), procedural assumptions (e.g., crew-dependent procedures for top-of-descent maneuvers or approaching the runway), and variations in navigation and surveillance accuracy; all of these generate trajectory prediction uncertainty.

TPSU research will focus on accurately estimating the prediction uncertainty and devising mechanisms by which this uncertainty can be accommodated in decisionmaking, particularly as applied to conflict management, as well as methods to dynamically predict uncertainty for use by stochastically based automation in mitigating its impact.

Beyond basic trajectory modeling research, TPSU strives to develop commonality between different modeling tools, with an emphasis on interoperability between aircraft-based flight management system (FMS) and the numerous ground systems. TPSU envisions a common language for the fast but explicit communication of trajectories among various entities.

Three NRA subtopics support TPSU:

- Development of Algorithms and Techniques for Trajectory Prediction Accuracy and Uncertainty Estimation – Addresses capability documentation, algorithm development, uncertainty assessment, intent error, and validation of NextGen TP tools.
- Traffic Complexity Management through Preserving Trajectory Flexibility and Minimizing Constraints – Addresses uncertainty in conflict management, preservation of trajectory flexibility, 4D flight management, and trajectory export.
- Cross Comparable Trajectory Predictor Requirements – Addresses documentation of capabilities.

TPSU Supported R&D Needs

There are three NextGen functional areas that call for the research in improved trajectory analysis carried out in TPSU: Trajectory-Based and Performance-Based Operations and Support, Weather Information Services, and Environmental Management Framework. The first of these encompasses three subareas, two of which, Air Navigation Operations and Air Navigation Support (ANS), are supported by TPSU. Each of the applicable functional areas and subareas is described below, along with the corresponding R&D needs identified in JPDO documentation.

The Air Navigation Operations subarea describes the air- and landside improvements that enable passenger and cargo flight operations to be conducted within the limits of safety, efficiency, available resources, and local environmental issues. Within this subarea, R&D need D-0520 calls for the development of methodologies to predict trajectories, including those for new classes of vehicles, as shown in Table 2.4.1-I. R-0380 calls for research on aircraft-derived position and intent to support data exchange in high-density terminal areas. R-0820 calls for research on 4D trajectory intent data for separation procedures, R-1620 calls for traffic spacing alternatives to support operations in congested en route airspace, R-1630 calls for technologies and procedures for flow corridors to support alternatives selection on the use of flow corridors and the associated air and ground technologies, and D-0830 entails development of protocols to negotiate trajectories for supporting an implementation decision on the aircraft and ground information architectures.

The Air Navigation Support subarea addresses the operational improvements necessary to establish criteria for designing and managing structured airspace in order to safely and efficiently support the flow of traffic. TPSU encompasses six R&D needs related to ANS. These include investigations on the use of 4D trajectories in clearances and flight plans to support alternatives selection decisions (R-0140), research on adaptable airspace structures to support the selection of performance-based adaptable airspace structures (R-0540), research for translating probabilistic weather information into safety and efficiency impacts (R-0570), and research on the benefits of dynamic allocation of resources (R-0680, R-0770). Additionally, R-0650 calls for research exploiting performance-based trajectories for efficient utilization of high-density terminal airspace.

The Weather Information Services functional area provides a common weather picture through the development of a single authoritative source of weather data. This is accomplished through the timely and integrated collection of current weather information, the development of detailed forecasts, and the dissemination of weather information in common and consolidated formats. R-0580 calls for the development of the first generation of probabilistic weather forecasts (e.g., convective and winter storms, icing, turbulence, ceiling, and visibility) to support interagency implementation decisions.

The Environmental Management Framework functional area seeks to balance the competing goals that will allow sustained aviation growth while reducing noise and aircraft engine emissions in absolute terms, as well as to improve management of environmental issues, including water quality, energy intensity, and global climate change. R&D need D-1730 calls for the development of aircraft control technologies and procedures that reduce noise and greenhouse gas emissions while improving local air quality, and R-1340 calls for protocols to negotiate trajectories to support an implementation decision on the aircraft and ground information architectures.

Table 2.4.1-I, which follows, presents the NextGen R&D needs and associated OIs that are addressed by TPSU research activities.

Table 2.4.1-I NextGen R&D Needs Addressed by TPSU

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-0520	Complete development of methodologies to predict trajectories, including those for new classes of vehicles, including UAS, very light, very large, and supersonic vehicles.	2012	OI-0343: Reduced Separation - High Density En Route, 3-mi.
D-0830	Complete development of protocols to negotiate trajectories for supporting an implementation decision on the aircraft and ground information architectures.	2010	OI-0302:Initial Collaborative In-flight Rerouting OI-0303: Improved Collaborative Traffic Management Initiatives OI-0306: Automation-Assisted Flight Plan Negotiation
D-1730	Complete development of aircraft operational control technologies and operational approaches to enable maximum use by the commercial fleet of air terminal and air space operational procedures that reduce noise, local air quality impact, and greenhouse gas emissions.	2013	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures, OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
R-0140	Complete initial applied research on the use of 4DT in clearances and flight plans to support an alternatives selection decision for further development and incorporation into future flight planning systems, ATM automation, and aircraft flight management systems.	2010	OI-0306: Automation-Assisted Flight Plan Negotiation
R-0380	Complete applied research on aircraft-derived position and intent information to support the definition of initial data exchange requirements for advanced application in high density terminal areas.	2011	OI-0326: Airborne Merging and Spacing - Single Runway
R-0540	Complete applied research on adaptable airspace structures, including corridors, to support an alternative selection of performance-based adaptable airspace structures.	2012	OI-0351: Airspace Reconfiguration - Level 1 Limited Dynamic En Route OI-0361: Flexible Resource Allocation for Airspace Management
R-0570	Complete applied research for an initial set of NextGen methodologies for translating probabilistic weather information into safety and efficiency impacts, as well as a capability to evaluate the derived operational information improvement.	2012	OI-0303: Improved Collaborative Traffic Management Initiatives OI-2010: Net-Enabled Common Weather Information Infrastructure

Table 2.4.1-I (Continued) NextGen R&D Needs Addressed by TPSU

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0580	Complete development of the first generation of probabilistic weather forecasts (e.g., convective and winter storms, icing, turbulence, ceiling, and visibility) to support interagency implementation decisions.	2012	OI-2010: Net-Enabled Common Weather Information Infrastructure OI-2020: Net-Enabled Common Weather Information - Level 1 Initial Capability
R-0650	Complete applied research on airspace design flexibility and techniques for exploiting performance-based trajectories to support an alternative decision on safe and efficient utilization of high-density terminal airspace.	2012	OI-0338: Efficient Metroplex Merging and Spacing OI-0339: Integrated Arrival/Departure and Surface Traffic Management for Metroplex OI-0342: Airspace Reconfiguration - Level 4 Dynamic Arrival/Departure
R-0680	Complete applied research on methodologies for the dynamic allocation of NAS resources (including use of airspace for military and other national missions) and ANSP resources to support a policy decision for how services and access will be equitably and dynamically distributed in a performance-based operation.	2012	OI-0337: Flow Corridors - Level 1 Static OI-0365: SUA Airspace Management - Level 2 Improved Coordination OI-0367: Airspace Reconfiguration Level 3 - Dynamic En Route
R-0770	Complete applied research on dynamically allocate demand to facilities to support an alternative selection to increase productivity, maintain capacity, and manage workload.	2012	OI-0307: Airspace Reconfiguration - Level 2 - Limited Dynamic Arrival/Departure OI-0342: Airspace Reconfiguration - Level 4 Dynamic Arrival/Departure OI-0365: SUA Airspace Management - Level 2 Improved Coordination
R-0820	Define 4DT intent data outputs and associated precision requirements for fixed and variable separation procedures (e.g., aircraft- and ground-based operations) to support implementation decisions on TBO in performance-based airspace.	2013	OI-0357: Trajectory-Based Mgmt - Level 1 Route/Trajectory Digital Exchange

Table 2.4.1-I (Continued) NextGen R&D Needs Addressed by TPSU

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-1340	Complete development of aircraft surface movement, arrival and departure, and en route procedures to maintain throughput while reducing environmental impacts to support an implementation decision on procedures and associated technologies by air navigation service providers and flight operators.	2015	OI-6020: Implement EMS Framework - Level 2
R-1620	Complete applied research on initial traffic spacing management alternatives to support an alternative selection on trajectory management, merging, spacing, and metering in congested en route airspace.	2011	(None identified in the IWP)
R-1630	Complete applied research on technologies and procedures for flow corridors to support alternatives selection on the use of flow corridors and the associated air and ground technologies.	2016	OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only OI-0361: Flexible Resource Allocation for Airspace Management

Alignment of TPSU Milestones with R&D Needs

This section describes the alignment between TPSU research and NextGen R&D needs. It begins with a discussion of the TPSU research activities that apply to the four NextGen functional areas and subareas of interest and concludes with a direct mapping of milestones to R&D needs.

The TPSU activities that support the Air Navigation Operations subarea include:

- Development and validation of vertical and horizontal profile algorithms for overconstrained trajectory parameters and for modeling multiple altitude and speed constraints of arbitrary order.
- Development of vertical and horizontal profile algorithms to model complex combinations of trajectory constraints stemming from NextGen 4D trajectory-based operations.
- Validation of initial trajectory modeling methods for representing NextGen-relevant approach and departure procedures.
- Survey and advance algorithms for predicting and describing propagation of trajectory uncertainty.
- Development of methodologies to account for trajectory prediction uncertainty in airborne conflict management to reduce the number of missed and false conflict alerts.

The Air Navigation Support subarea sets forth several R&D needs related to designing and managing structured airspace. Within the TPSU RFA there is considerable work to address this need; the complete set, in terms of milestones, appears in Table 2.4.1-II, below. A paraphrased sample of the milestones includes:

- Document the trajectory prediction and modeling algorithms and software capability requirements envisioned to support NextGen automation systems
- Develop algorithms for measuring differences among 4D trajectories

- Identify and quantify sources of uncertainty for trajectory prediction and advanced algorithms for predicting propagation of trajectory uncertainty
- Identify and quantify a complete set of constraints and objective functions for trajectories to support ATM functions
- Develop analysis tools and assemble validation datasets from high-fidelity sources for use in trajectory prediction validation studies.

The Weather Information Services functional area is supported by the following milestone:

- Identify and quantify sources of uncertainty for trajectory prediction.

The Environmental Management Framework functional area is supported by the following TPSU milestone:

- Advanced algorithms for predicting and describing propagation of trajectory uncertainty.

Table 2.4.1-II, below, shows the TPSU milestones that address the R&D needs summarized above.

Table 2.4.1-II TPSU Milestones Linked to NextGen R&D Needs

TPSU Milestone	Title	Year	Applicable NextGen R&D Needs
AS.1.1.01	Survey and document the current SOA of trajectory prediction/modeling algorithms and software capabilities and the requirements envisioned for trajectory prediction to support NextGen automation systems.	2007	D-0520, R-0140, R-0820
AS.1.1.02	Survey and document the trajectory prediction/modeling algorithms and software capabilities (e.g., EDA, PARR, 4D-FMS) supporting the current state of the art (TMA, URET, FMS), and requirements envisioned for future TP capabilities to support NextGen-relevant trajectory prediction for the Evaluator and related automation.	2007	D-0520, R-0140, R-0380, R-0820
AS.1.1.03	Develop algorithms for measuring the difference between 4D trajectories.	2007	D-0520, R-0140, R-0820
AS.1.1.04	Identify and quantify a complete set of constraints and objective functions typically applied to trajectories to support ATM functions.	2007	D-0520, R-0140, R-0540, R-0650, R-0680, R-0770, R-0820, R-1620, R-1630
AS.1.1.05	Identify and quantify sources of uncertainty for trajectory prediction.	2007	D-0520, R-0140,R-0570, R-0580, R-0820
AS.1.1.06	Develop data mining techniques for identifying trends in trajectory intent error.	2008	D-0520, R-0140, R-0820
AS.2.1.01	Develop scripting language and protocols for a common-trajectory-model architecture (in collaboration with U.S. (FAA) and European trajectory-prediction research organizations (Eurocontrol)).	2008	D-0520, D-0830, R-0140, R-0380, R-0820

Table 2.4.1-II (Continued) TPSU Milestones Linked to NextGen R&D Needs

TPSU Milestone	Title	Year	Applicable NextGen R&D Needs
AS.2.1.02	Development of analysis tools and ensemble validation datasets (representing a statistically significant set of trajectory-prediction conditions envisioned under NextGen) from high-fidelity simulation, ATC radar and flight-plan data, field assessments, and flight-data recordings for use in trajectory prediction validation studies conducted by U.S. laboratories supporting NextGen.	2008	D-0520, R-0140, R0820
AS.2.1.03	Develop vertical and horizontal-profile algorithms to model complex combinations of trajectory constraints (stemming from NextGen 4D trajectory-based operations) involving multiple “simultaneous” constraints (e.g., path, speed, altitude, and/or time) for en route, transition (to terminal), and terminal airspace. Validate algorithms for en route and transition airspace.	2008	D-0520, R-0140, R-0820
AS.2.1.04	Survey and advance algorithms for predicting and describing propagation of trajectory uncertainty.	2008	D-0520, R-0140, R-1340, D-1730, R-0820
AS.2.1.05	Validate vertical and horizontal-profile algorithms for trajectory smoothness and robustness criteria for over-constrained trajectory parameters in en route and transition airspace.	2009	D-0520, R-0140, R-0820
AS.2.1.06	Develop and validate vertical and horizontal-profile algorithms for modeling multiple altitude and speed constraints of arbitrary order within en route and transition airspace.	2009	D-0520, R-0140, R-0820
AS.3.1.01	Develop, validate, and document Common Trajectory Model algorithms and capabilities for NextGen applications within en-route and transition airspace.	2008	D-0520, R-0140, R-0820
AS.3.1.02	Common Trajectory Model algorithms validated terminal airspace, documenting accuracies and robustness.	2009	D-0520, R-0140, R-0380, R-0820
AS.3.1.03	Comprehensive assessment of NextGen-relevant trajectory-intent errors.	2009	D-0520, R-0140, R-0820
AS.3.1.04	Validation of initial trajectory modeling methods for representing NextGen-relevant (e.g., FAA) approach/departure procedures through terminal airspace, accounting for specific runway, altitude and speed scheduling.	2010	D-0520, R-0140, R-0380, R-0820

2.4.2 Performance-Based Services (PBS)

PBS Description

PBS develops classification systems and assesses performance capabilities needed to enable a shift toward air traffic services and operations requirements based on system performance capabilities rather than on equipment type.

A major goal of PBS research is to understand and define this performance framework, its associated levels of performance, and the commensurate levels of service, all critical steps toward the NextGen vision. PBS combines the fundamental building blocks of Required Navigation Performance (RNP), Required Communication Performance (RCP) and Required Surveillance Performance (RSP) into the aggregate multidimensional parameter of Required Total System Performance (RTSP). The application-specific functions of PBS that can be enabled individually or concurrently include time-of-arrival conformance, airborne spacing, and airborne separation.

PBS research embodies two major topics: (1) development of a conceptual framework for identifying the relevant relationships among new concepts for aircraft operations, performance of airborne and ground-based applications, and performance of supporting systems, and (2) development and implementation of models of performance characteristics for communication, navigation, and surveillance systems related to new concepts for aircraft operations.

Four NRA subtopics support PBS:

- Development of an Innovative Structural Framework to Identify the Airborne and Ground-based Applications and Performance Capabilities Needed to Support NextGen – Evaluates the usefulness of identifying specific levels or potential groupings of application and system performance as criteria for identifying the ability of an aircraft to participate in proposed flight operations, and proposes approaches for specifying the RTSP necessary to enable NextGen concepts of operation.
- Integration of Weather Data into Airspace and Traffic Operations Simulation (ATOS) for Trajectory-Based Operations Research – Provides recorded and simulated convective weather, forecast, wind, and temperature data, and incorporates it into the Airspace and Traffic Operations Simulation (ATOS) environment in formats suitable for display and processing by airborne trajectory-management automation.
- Development of New Models (or Extending Existing Models) of the Communications, Navigation, and Surveillance (CNS) System Capabilities Required to Support the Applications that Enable New Concepts of Aircraft Operations Proposed for NextGen – Ensures that these models represent their respective systems to a level sufficient to capture the applicable characteristics that have important impacts on system performance, and conducts assessments of these models to support parametric batch simulation studies.
- Theoretical Basis for Extending the Concept of Required Navigational Performance to Four-Dimensional Navigation in Fixed and Dynamic Frames of Reference – Assists NASA in developing the theoretical basis for extending the concept of RNP to 4D navigation in fixed and dynamic frames of reference, known as 4D Dynamic RNP.

PBS Supported R&D Needs

PBS is closely linked to the NextGen key capability of Performance Based Operations (PBO). The primary goal of PBO is to provide different levels of service to users of the aviation system based on the functional capabilities of their aircraft and of ground-based systems by matching Air Navigation Service Provider (ANSP) service levels to user performance capabilities. Defining multiple service levels addresses a wide range of user needs while encouraging more private sector innovation and free market decisionmaking. This allows users to select the performance level appropriate to their particular operation and reduces the need to dictate specific equipment requirements. This effort will also provide a tool for controlling access to highly constrained resources and/or complex operating environments. Understanding and defining this performance framework, its associated levels of performance, and the commensurate levels of service, are critical steps toward reaching the NextGen vision.

Three NextGen functional areas or subareas are supported by this RFA: Air Navigation Operations, Flight Operations and Support, and Safety Management.

PBS addresses five R&D needs related to the Air Navigation Operations subarea. PBS research will support the development of options, standards, and decision-support aids to enable variable separation standards based on performance levels (R-0500, see Table 2.4.2-I), define 4D trajectory intent data outputs and their precision requirements to support TBO in performance-based airspace (D-0820), and develop aircraft-based CNS performance-level requirements for self-separation (D1600). It will also support research on options for automated separation management to guide development of technology and procedures in performance-based airspace (R-0530) and on the development of three-dimensional RNAV/RNP procedures (R-0340).

The Flight Operations and Support subarea describes the improvements needed for aircraft and aircraft-related systems in NextGen. This RFA supports that subarea with research on priorities for aircraft capabilities to support alternative selection and policy for standards development and certification (R-0040).

The Safety Management functional area addresses safety initiatives that enhance the safety of aviation systems or improve safety processes. Its R&D needs that are supported by PBS include development of human and system performance models that capture human variability and error in highly automated systems (D-1690) and research on systems interfaces, performance models, procedures, and training to complement the development of automation procedures (D-1710).

Table 2.4.2-I, below, shows the NextGen R&D needs and associated OIs that are addressed by PBS research activities.

Table 2.4.2-I NextGen R&D Needs Addressed by PBS

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-1690	Complete development of human-system performance models that accurately capture human variability and human error in highly automated NextGen systems to support applied research on high-level roles and responsibilities of human operators and automation in NextGen systems.	2011	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-1710	Complete applied research on risk-reducing systems interfaces, procedures, and training to reduce human error and complement the development of automation procedures for the range of NextGen stakeholders.	2015	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only

Table 2.4.2-I (Continued) NextGen R&D Needs Addressed by PBS

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0040	Complete applied research on aircraft capability priorities for NextGen through 2015 to support alternative selection and policy for standards development and certification.	2009	OI-0334: Independent Parallel or Converging Approaches in IMC OI-0335: Dependent Multiple Approaches in IMC OI-0338: Efficient Metroplex Merging and Spacing OI-0343: Reduced Separation - High Density En Route, 3-mi. OI-0362: Self-Separation - Self-Separation Airspace OI-0363: Delegated Separation - Complex Procedures
R-0340	Complete development of three-dimensional RNAV/RNP procedures for implementation decision.	2011	(None identified in the IWP)
R-0500	Complete applied research on options for procedures, standards specification, decision-support aids, and displays to support an alternative selection to enable variable separation standards based on performance levels in all airspace.	2012	OI-0329: Airborne Merging and Spacing with CDA OI-0343: Reduced Separation – High Density En Route, 3-mi.
R-0530	Complete applied research on ground and aircraft automated separation management options to guide the selection of technology and procedures development for TBO in performance-based airspace.	2012	OI-0355: En Route Airborne Merging and Spacing OI-0362: Self-Separation - Self-Separation Airspace OI-0363: Delegated Separation - Complex Procedures
R-0820	Define 4DT intent data outputs and associated precision requirements for fixed and variable separation procedures (e.g., aircraft- and ground-based operations) to support implementation decisions on TBO in performance-based airspace.	2013	OI-0357: Trajectory-Based Mgmt – Level 1 Route/Trajectory Digital Exchange

Table 2.4.2-I (Continued) NextGen R&D Needs Addressed by PBS

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-1600	Complete applied research on aircraft-based communications, navigation, and surveillance (CNS) performance levels to develop requirements for self-separation.	2016	OI-0359: Delegated Separation – Oceanic OI-0362: Self-Separation - Self-Separation Airspace OI-0363: Delegated Separation - Complex Procedures

Alignment of PBS Milestones with R&D Needs

The text which follows summarizes the alignment of PBS milestones with NextGen R&D needs in the functional areas discussed above.

The Air Navigation Operations and Air Navigation Support subareas include several R&D needs related to the development of options, standards, and decision-support aids to enable variable separation standards. Milestones that address these needs include:

- Identify techniques for modeling RTSP characteristics and provide extensions of such techniques.
- Conduct parametric RTSP batch studies of AAC and 4D-ASAS concepts under nominal and failure mode conditions.
- Complete human-in-the-loop studies of AAC and 4D-ASAS using minimum RTSP levels determined by previously performed batch studies.
- Produce a list of performance attributes corresponding to the list of candidate operational concepts and grouping the attributes under RNP, RCP, RSP, or an advanced performance measure.

For the Flight Operations and Support subarea, PBS efforts to synthesize human factors and operational literature address the need to identify alternatives selection and policy for standards development and certification.

Specific PBS milestones address R&D needs of the Safety Management functional area related to risk-reducing systems interfaces, performance models, procedures, and training to reduce human error. These R&D needs include:

- Synthesizing literature on human factors and operations, which supports multiple needs across functional areas.
- Producing a comprehensive list of performance attributes corresponding to the list of candidate NextGen operational concepts.

Table 2.4.2-II, which follows, shows the PBS milestones that address the R&D needs summarized above.

Table 2.4.2-II PBS Milestones Linked to NextGen R&D Needs

PBS Milestone	Title	Year	Applicable NextGen R&D Needs
AS.1.2.01	Identify suitable techniques for modeling RTSP performance characteristics.	2008	R-0820, R-1600
AS.1.2.02	Synthesis of human factors and operational literature.	2008	D-1690, D-1710, R-0040, R-1600
AS.1.2.03	Extensions of analytical and statistical techniques for modeling RTSP performance characteristics.	2009	R-0820, R-1600
AS.1.2.04	Identify grouping techniques that will classify/represent the multidimensional nature of RTSP performance characteristics. Identify decision support and information presentation techniques applicable to grouping techniques.	2010	R-0820, R-1600
AS.2.2.01	Produce a comprehensive list of performance attributes corresponding to the list of candidate NextGen operational concepts.	2007	D-1710, R-0500, R-0820, R-1600
AS.2.2.02	Working with industry and the JPDO Shared Situation Awareness IPT, produce a set of parametric performance models of CNS systems.	2007	R-0340, R-0500, R-0820, R-1600
AS.2.2.03	Group the performance attributes under RNP, RCP, RSP, or an advanced performance measure.	2008	R-0340, R-0500, R-0820, R-1600
AS.2.2.04	CNS performance models are integrated into simulation systems and their performance is verified by actual operational data, where available.	2008	R-0500, R-0820, R-1600
AS.3.2.01	Produce a list of candidate NextGen operational concepts.	2007	R-0820, R-1600
AS.3.2.02	Produce a detailed hierarchical structure of RTSP elements and advanced performance measures needed to support candidate NextGen operational concepts.	2008	R-0500, R-0820, R-1600
AS.3.2.03	Working with industry and JPDO Shared Situation Awareness IPT, define the parameters associated with RCP and RSP.	2009	R-0500, R-0820, R-1600
AS.3.2.04	Parametric RTSP batch studies of AAC and 4D-ASAS concepts are completed under nominal and failure mode conditions.	2009	R-0500, R-0530, R-0820
AS.3.2.05	Human-in-the-loop studies of AAC and 4D-ASAS concepts are completed using minimum RTSP levels determined by previously performed batch studies.	2009	R-0500, R-0530, R-0820, R-1600

2.4.3 Dynamic Airspace Configuration (DAC)

DAC Description

DAC increases capacity through strategic airspace organization and dynamic allocation of airspace structures and controller resources. Research topics include the requirement to (1) develop overall classifications of airspace, (2) identify new classes of airspace for NextGen operations, (3) develop algorithms and technologies for dynamically changing airspace to make it adaptable to accommodate demand, and (4) develop generic airspace characteristics to increase interchangeability of facilities and controllers.

The DAC function consists of two major components: (a) the overall organization of airspace, and (b) the ability to change the airspace structure (e.g., sectorization scheme). The organizational elements of a dynamic airspace may include, but are not limited to, tubes or high-density corridors in the sky, 4D trajectory airspace and traditional airspace, and new classes of airspace based on advanced concepts such as automated separation. The time horizon within which traffic managers could be expected to reconfigure airspace can range from months to days to hours.

Research activities for the organizational component include identifying the characteristics of the current airspace system that may limit airspace efficiency. This effort will identify a route structure that may be necessary to support NextGen operations under nominal and off-nominal conditions. The airspace classes and airspace configuration concepts that serve as building blocks will also be identified. Algorithms will be developed to identify these airspace classes based on traffic demand, weather, and the required route structure. The benefits of these new airspace classes will be identified under varying traffic load and weather conditions, as will the benefits to NextGen.

Airspace structural changes are implemented based on predicted traffic demand, aircraft equipage, and weather conditions to allow adjustment of the airspace capacity based on the traffic demand, forecasted weather, and expected equipage. Activities for this component include the identification of the characteristics of current airspace design and practices that limit routine changes in the airspace to better balance demand and capacity. Algorithms will be developed to create a set of airspace configuration schemes based on traffic, weather, equipage, and routes.

Two NRA subtopics support DAC:

- Overall Airspace Organization and Dynamic Airspace Allocation Schemes – Develops advanced concepts and algorithms for future airspace classes and develops advanced concepts and algorithms for routinely changing airspace configuration to balance capacity and demand based on the expected traffic density, aircraft equipage, and weather forecast.
- Characteristics of Generic Airspace and Design of Airspace Referencing Scheme – Develops characteristics of generic airspace and airspace referencing schemes to support the generic airspace, an airspace structure that could be implemented repeatedly in multiple locations regardless of geographical considerations.

DAC Supported R&D Needs

The NextGen goal for DAC is to better serve users' needs by tailoring the availability and capacity of the airspace. This is done by creating a dynamic configuration function that gives the service provider a new degree of freedom to accommodate the airspace requests of users. DAC addresses one R&D need related to the Air Navigation Operations subarea and eight R&D needs related to the Air Navigation Support subarea.

For Air Navigation Operations, DAC addresses the R&D need for applied research on technologies and procedures for flow corridors and the associated air and ground technologies (R-1630).

Capacity Management (CM) is one element of Air Navigation Support. Capacity Management is the design and configuration of airspace and the allocation of other air traffic management resources. It is the preferred means of responding to dynamic forecast demand, whereby resources and performance-based services are matched with the expected demand. Capacity management needs addressed by DAC include research on methodologies for the dynamic allocation of NAS and ANSP resources (R-0680), research on airspace structure elements to reduce controller training time (R-0280), development of limited dynamic reconfiguration of arrival and departure airspace air traffic management personnel assignments and facilities to match traffic flows (D-1090), and development of technologies and procedures for dynamically adjustable advanced airspace structures for execution and for dissemination of information (D-1210).

A second element of Air Navigation Support is Flow Contingency Management (FCM). FCM needs addressed by DAC include research on the ability to detect the need for and to implement changes to the airspace structure (e.g., sectorization scheme) based on predicted traffic demand, aircraft equipage, and weather conditions to allow adjustment of the airspace capacity, where needed, based on traffic demand, forecasted weather, and expected equipage (R-0540, R-0650, R-0770, R-1130).

Table 2.4.3-I, below, shows the NextGen R&D needs and associated OIs that are addressed by DAC research activities.

Table 2.4.3-I NextGen R&D Needs Addressed by DAC

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-1090	Complete development of limited dynamic reconfiguration of arrival and departure airspace to support an implementation decision on dynamic allocation of air traffic management personnel and facilities to match traffic flows.	2014	OI-0337: Flow Corridors - Level 1 Static
D-1210	Complete development of technologies and procedures for dynamically adjustable advanced airspace structures, matched to demand and national needs (including airspace for special use), to support an implementation decision on the execution and dissemination of information on dynamic airspace structures.	2015	OI-0342: Airspace Reconfiguration - Level 4 Dynamic Arrival/Departure
R-0280	Complete applied research on airspace structure elements to reduce controller training time, to support an alternative selection on the airspace elements and related controller tasks.	2011	OI-0307: Airspace Reconfiguration - Level 2 - Limited Dynamic Arrival/Departure
R-0540	Complete applied research on adaptable airspace structures, including corridors, to support an alternative selection of performance-based adaptable airspace structures.	2012	OI-0351:Airspace Reconfiguration - Level 1 Limited Dynamic En Route OI-0361: Flexible Resource Allocation for Airspace Management

Table 2.4.3-I (Continued) NextGen R&D Needs Addressed by DAC

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0650	Complete applied research on airspace design flexibility and techniques for exploiting performance-based trajectories to support an alternative decision on safe and efficient utilization of high-density terminal airspace	2012	OI-0338: Airborne Merging and Spacing for Metroplex OI-0339: Integrated Arrival/Departure and Surface Traffic Management for Metroplex OI-0342: Airspace Reconfiguration - Level 4 Dynamic Arrival/Departure
R-0680	Complete applied research on methodologies for the dynamic allocation of NAS resources (including use of airspace for military and other national missions) and ANSP resources to support a policy decision for how services and access will be equitably and dynamically distributed in a performance-based operation.	2012	OI-0337: Flow Corridors - Level 1 Static OI-0365: SUA Airspace Management - Level 2 Improved Coordination OI-0367: Airspace Reconfiguration Level 3 - Dynamic En Route
R-0770	Complete applied research on dynamically allocate demand to facilities to support an alternative selection to increase productivity, maintain capacity, and manage workload.	2012	OI-0307: Airspace Reconfiguration - Level 2 - Limited Dynamic Arrival/Departure OI-0342: Airspace Reconfiguration - Level 4 Dynamic Arrival/Departure OI-0365: SUA Airspace Management - Level 2 Improved Coordination
R-1130	Complete applied research on automated capacity problem detection, notification, coordination, and resolution to support an alternative selection for capacity management capabilities.	2014	OI-0306: Automation-Assisted Flight Plan Negotiation
R-1630	Complete applied research on technologies and procedures for flow corridors to support alternatives selection on the use of flow corridors and the associated air and ground technologies.	2016	OI-0361: Flexible Resource Allocation for Airspace Management OI-0368: Flow Corridors - Level 2 Dynamic

Alignment of DAC Milestones with R&D Needs

Alignment of DAC milestones with NextGen R&D needs in the two subareas of Air Navigation Operations and Air Navigation Support is summarized as follows.

DAC milestones that address R&D needs in the Air Navigation Operations subarea include:

- Surveying and documenting the body of research and literature which accurately describes the present understanding of Air Navigation Operations and Air Navigation Support.
- Documenting the elements of airspace structure in the NAS and best practices identified and adapted for NextGen.

The Air Navigation Support subarea identifies several R&D needs related to the design and configuration of airspace and the allocation of other air traffic management resources. ATM-Airspace Project milestones that address these needs include:

- Utilizing formal mathematical methodologies to develop dynamic airspace structures supporting both new and conventional classes of airspace.
- Proposing and validating candidate airspace allocation algorithms.

Table 2.4.3-II, below, shows the DAC milestones that address the R&D needs summarized above.

Table 2.4.3-II DAC Milestones Linked to NextGen R&D Needs

DAC Milestone	Title	Year	Applicable NextGen R&D Needs
AS.1.3.01	The State of the Art is surveyed and documented.	2007	D-1090, D-1210, R-0280, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630
AS.1.3.02	The elements of airspace structure in the NAS are inventoried, and “best practices” in airspace design are documented. Adapt for NextGen.	2007	D-1090, D-1210, R-0280, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630
AS.1.3.03	Utilize formal mathematical methodologies, such as genetic algorithms and neural networks, to develop dynamic airspace structures supporting both new and conventional classes of airspace.	2010	D-1090, D-1210, R-0280, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630
AS.2.3.01	Candidate airspace allocation algorithms proposed.	2009	D-1210, R-0280, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630
AS.2.3.02	Candidate airspace allocation algorithms validated.	2010	D-1210, R-0280, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630
AS.3.3.01	Categorize events that trigger airspace reconfiguration.	2008	D-1090, D-1210, R-0280, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630
AS.3.3.02	Develop an operational framework for dynamic airspace configuration.	2008	D-1090, D-1210, R-0280, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630
AS.3.3.03	Airspace complexity limits for each class of airspace are analytically validated.	2008	D-1090, D-1210, R-0280, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630
AS.3.3.04	Validate by simulation that airspace could be reconfigured every four hours without adverse effects.	2009	D-1090, D-1210, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630

Table 2.4.3-II (Continued) DAC Milestones Linked to NextGen R&D Needs

DAC Milestone	Title	Year	Applicable NextGen R&D Needs
AS.4.3.01	Dynamic airspace configuration concepts experimentally validated.	2011	D-1090, D-1210, D-1710, R-0280, R-0540, R-0650, R-0680, R-0770, R-1130, R-1630

2.4.4 Traffic Flow Management (TFM)

TFM Description

TFM identifies and resolves imbalances in the demand and supply of NAS resources, such as airspace and runways. This activity addresses the requirements to (1) assimilate weather into TFM by exploring the impact of weather (convective and nonconvective) on the capacity of NAS resources, (2) explore the roles and responsibilities of airspace users on TFM decisionmaking, (3) develop and explore the utility of both aggregate (i.e., flow-based) and aircraft-level flow control models, and (4) develop heuristic and optimization approaches for developing optimal flow control strategies (e.g., rerouting, departure control, airborne flight delays).

The overall technical approach of the TFM research focus area is a natural progression from concept development to building core capabilities (namely, weather impact and collaborative decisionmaking) to testing and evaluation. It is organized into four initiatives: (a) Advanced TFM Concepts, (b) Collaborative Decision Making in TFM, (c) Weather Impact on TFM, and (d) Simulation and Evaluation of TFM Concepts.

Advanced TFM Concepts focuses on the development of advanced TFM techniques that contribute to the goal of tripling NAS capacity by leveraging key features of NextGen, such as 4D trajectory-based operations, performance-based operations, automated separation assurance, and super-density operations. A key research challenge is to develop techniques for an Evaluator that utilize both individual and aggregated 4D trajectories to organize, schedule, and regulate traffic flow in accordance with calculated NAS capacity constraints. The output of this effort is an integrated set of advanced TFM concepts and the associated algorithms and models that will be essential to the development of the Evaluator.

Another aspect of this work is the definition of relationships and operational transitions among the TFM, Dynamic Airspace Configuration, and Separation Assurance RFAs. This activity includes development of advanced techniques to assess the impact of TFM initiatives under both deterministic and stochastic scenarios. Candidate initiatives to be examined include rerouting and departure control at the national level; merging, spacing, and sequencing at the local level; and sequencing and scheduling in multi-airport terminal areas. The benefits and utility of these TFM control strategies will also be assessed as part of this activity. The output of this effort will be a baseline Evaluator concept of operations that describes the composition and architecture of TFM functions as well as their temporal and geographic scope.

Collaborative Decision Making (CDM) in TFM focuses on the development of a methodology to incorporate user preferences into traffic flow management. This activity involves determining appropriate roles and procedures that enable users and the air traffic service providers to collaboratively design efficient and equitable traffic management processes. Advanced tools and protocols will be developed for formulating, evaluating, and implementing these collaboratively designed schemes. The output of this activity will be algorithms, procedures, and protocols for fully integrating CDM into the TFM process.

Weather Impact activities in TFM will develop probabilistic models to forecast demand and capacity of NAS resources. The technical challenge is to develop modeling techniques that are robust to uncertainties such as weather conditions and substantial variations in user demand profiles. These stochastic forecasts are necessary for designing TFM control strategies (e.g., rerouting, departure delay, sequencing, and scheduling) that will balance the forecasted supply and demand profiles in an equitable and optimal manner. The outputs of this activity are probabilistic models and algorithms, as well as requirements for weather products, to enable improved predictions of supply and demand on NAS resources under uncertainty.

Simulation and Evaluation of TFM Concepts will develop prototype tools to implement advanced TFM concepts employing 4D trajectories. This activity focuses on the implementation of various algorithms (e.g., probabilistic predictions of NAS resource demand and supply, regional metering and/or spacing, ground delay, and customized rerouting incorporating user preferences) in a NAS simulation environment such as the Future ATM Concepts Evaluation Tool (FACET). The output of this effort is a suite of advanced TFM tools integrated into a simulation test bed.

The following is a sample of NRA subtopics that support TFM:

- Dynamic Stochastic Models for Managing Air Traffic Flows – Addresses optimization of TFM and flow modeling (e.g., using aggregate flow and network methods).
- Theoretic Design & Numerical Evaluation of TFM Strategies Under Uncertainty – Evaluates the impacts of uncertain weather events on managed traffic flow and the development of coordinated flow.
- A Unified Approach to Strategic Models and Performance Evaluation for Traffic Flow Management – Addresses the development of empirical and data mining models to correlate weather and key metrics for NAS management strategies that can operate well in the presence of weather and other uncertainties.
- Development of Optimization Algorithms for TFM in the Presence of Uncertainty – Develops probabilistic and stochastic methods for flow management to address uncertainties in weather prediction.
- Development of Strategic Models and Performance Metrics for TFM using Data Mining and Statistical Methods – Develops empirical and data mining models for correlating weather and key metrics for NAS performance.
- Traffic Complexity – Develops traffic complexity metrics for manual, hybrid, and automated air traffic management operations that are more automated than is currently the case.

TFM Supported R&D Needs

Advanced TFM is a key element of NextGen. Its goal is to accommodate user-preferred gate-to-gate trajectories by managing and allocating NAS resources in situations where demand approaches or exceeds supply. TFM-related R&D needs come from four NextGen functional areas or subareas: Air Navigation Operations, Air Navigation Support, Weather Information Services, and Safety Management.

Air Navigation Operations subarea R&D needs include development of protocols to negotiate trajectories (D-0830) and research on requirements for optimizing flight profiles in oceanic airspace (R-1590).

R&D needs in the Air Navigation Support subarea include applied research on automation-assisted collaboration capabilities (R-0130, R-1120), use of 4DTs in flight planning and evaluation (R-0140, R-0960), and research associated with dynamic reconfiguration of airspace and assets (R-1090, R-0770). Research on detection of capacity problems is needed for R-1130, on automated integration of weather and other constraining information affecting demand and capacity by R-0660, and on an aggregate flow model by R-0420. Other ANS needs include the development of methodologies to translate probabilistic weather information into efficiency and safety impacts (R-0570) and the integration of probabilistic information, uncertainties, and other analyses into selection from among alternative solutions (R-1140).

In the Weather Information Services functional area, R&D need R-0580 calls for the development of the first generation of probabilistic weather forecasts including convective and winter storms, icing, turbulence, ceiling, and visibility, and D-0850 calls for the completion of development of a virtual, authoritative, net-centric four-dimensional weather information system that provides information tailored to ATM procedures, including routine elements (diagnostics and forecasts) and real-time, hazardous weather information to support an implementation decision on the network-enabled 4-D Weather Cube.

In the Safety Management functional area, R&D needs D-1700 and D-2100 call for research on risk assessment and certification issues; D-1710 calls for applied research on risk-reducing systems interfaces, procedures, and training to reduce human error and complement the development of automation procedures for the range of NextGen stakeholders; and D-1690 calls for development of system performance models to assess human and automation roles and responsibilities.

Table 2.4.4-I, below, shows the NextGen R&D needs and associated OIs that are addressed by TFM research activities.

Table 2.4.4-I NextGen R&D Needs Addressed by TFM

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-0420	Complete development of an NAS-wide aggregate flow model to support an implementation decision on capabilities supporting common situational awareness of current and forecast congestion and mitigation options among ATM personnel, flight operators, and flight crews.	2011	OI-0303: Improved Collaborative Traffic Management Initiatives OI-0305: Traffic Flow Management Alternatives Analysis
D-0830	Complete development of protocols to negotiate trajectories for supporting an implementation decision on the aircraft and ground information architectures.	2010	OI-0302:Initial Collaborative In-flight Rerouting OI-0303: Improved Collaborative Traffic Management Initiatives OI-0306: Automation-Assisted Flight Plan Negotiation

Table 2.4.4-I (Continued) NextGen R&D Needs Addressed by TFM

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-0850	Complete development of a virtual, authoritative, net-centric four-dimensional weather information system that provides information tailored to ATM procedures, including routine (diagnostics and forecasts) and real-time, hazardous weather information to support an implementation decision on the network-enabled 4-D Weather Cube.	2013	OI-2020: Net-Enabled Common Weather Information - Level 1 Initial Capability
D-1090	Complete development of limited dynamic reconfiguration of arrival and departure airspace to support an implementation decision on dynamic allocation of air traffic management personnel and facilities to match traffic flows.	2014	OI-0337: Flow Corridors - Level 1 Static
D-1690	Complete development of human-system performance models that accurately capture human variability and human error in highly automated NextGen systems to support applied research on high-level roles and responsibilities of human operators and automation in NextGen systems.	2011	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-1700	Complete development of system risk assessment and management models to applied research on the allocation of capabilities across flight operator and ANSP automation.	2012	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-1710	Complete applied research on risk-reducing systems interfaces, procedures, and training to reduce human error and complement the development of automation procedures for the range of NextGen stakeholders.	2015	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-2100	Complete development of methods for verification and validation of complex systems to support alternative NextGen risk assessment and certification decisions.	2013	(None identified in the IWP)
R-0130	Complete applied research on automation-assisted collaboration capabilities to support an alternative selection for further development and policy decision on the range of stakeholder participation in the collaboration process.	2010	OI-0306: Automation-Assisted Flight Plan Negotiation

Table 2.4.4-I (Continued) NextGen R&D Needs Addressed by TFM

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0140	Complete initial applied research on the use of 4DT in clearances and flight plans to support an alternatives selection decision for further development and incorporation into future flight planning systems, ATM automation, and aircraft flight management systems.	2010	OI-0306: Automation-Assisted Flight Plan Negotiation
R-0570	Complete applied research for an initial set of NextGen methodologies for translating probabilistic weather information into safety and efficiency impacts, as well as a capability to evaluate the derived operational information improvement.	2012	OI-0303: Improved Collaborative Traffic Management Initiatives OI-2010: Net-centric Common Weather Information for NextGen Decision-Making
R-0580	Complete development of the first generation of probabilistic weather forecasts (e.g., convective and winter storms, icing, turbulence, ceiling, and visibility) to support interagency implementation decisions.	2012	OI-2010: Net-Enabled Common Weather Information Infrastructure OI-2020: Net-Enabled Common Weather Information - Level 1 Initial Capability
R-0660	Complete applied research on automated integration of weather, environmental, aeronautical, security, and emergency information and on demand and capacity information to support an alternative selection and policy decision for tailored information services to meet specific needs.	2012	OI-0303: Improved Collaborative Traffic Management Initiatives
R-0670	Complete applied research regarding the applicability of “control by points” traffic management initiatives to support an alternatives selection decision for developing options for flight operators to manage flights within the context of time-based control points.	2012	OI-0306: Automation-Assisted Flight Plan Negotiation
R-0770	Complete applied research on dynamically allocate demand to facilities to support an alternative selection to increase productivity, maintain capacity, and manage workload.	2012	OI-0307: Airspace Reconfiguration - Level 2 - Limited Dynamic Arrival/Departure OI-0342: Airspace Reconfiguration - Level 4 Dynamic Arrival/Departure OI-0365: SUA Airspace Management - Level 2 Improved Coordination

Table 2.4.4-I (Continued) NextGen R&D Needs Addressed by TFM

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0960	Complete applied research on operator and ANSP capabilities for 4DT evaluation, planning, presentation, and negotiation to support alternative selection and policy for four-dimensional flight-planning and collaborative ATM.	2013	OI-0306: Automation-Assisted Flight Plan Negotiation
R-1120	Complete applied research on collaborative automated flight and flow evaluation and resolution capabilities to support an alternative selection on how flight operators and ANSP negotiate objectives and trajectory preferences to balance priorities, including roles and responsibilities.	2014	OI-0306: Automation-Assisted Flight Plan Negotiation
R-1130	Complete applied research on automated capacity problem detection, notification, coordination, and resolution to support an alternative selection for capacity management capabilities.	2014	OI-0306: Automation-Assisted Flight Plan Negotiation
R-1140	Complete applied research on integration of probabilistic information (e.g., weather, congestion), management of uncertainty, what-if analysis, and integrated incremental resolutions to support an alternative selection for how to achieve agile and effective incremental decisions.	2014	OI-0306: Automation-Assisted Flight Plan Negotiation OI-0310: Reduced Controlled Flight into Terrain OI-3012: Reduced Weather-Related Incidents-Level 1
R-1590	Complete applied research on requirements for optimizing flight profiles (e.g., ground- and aircraft-based solutions) to support an alternatives selection for altitude changes and co-altitude pair-wise maneuvers at reduced separation in oceanic airspace.	2013	OI-0353: Reduced Oceanic Separation - Altitude Change Pair-wise Maneuvers OI-0354: Reduced Oceanic Separation - Altitude Pair-wise Maneuvers OI-0356: Delegated Separation - Pair-wise Maneuvers

Alignment of TFM Milestones with R&D Needs

The ultimate objective of the TFM research focus area is to conduct the initial research required to develop an advanced TFM system in the future NAS. This advanced TFM system will accommodate user preferences, reduce delays, and increase efficiency under all weather conditions and significantly increased demand levels. Substantial research and development, with a range of subobjectives, is required to reach this overarching objective.

As can be seen from Table 2.4.4-II, most TFM milestones address a large number of NextGen R&D needs. Consequently, several milestones apply to more than one functional area, as described in the paragraphs below.

A major contribution of TFM is in the Air Navigation Operations subarea. Work in this subarea includes:

- Updating and refining Evaluator requirements.
- Developing and testing Evaluator concepts to increase efficiency under all weather conditions.
- Expanding Traffic Flow Management concepts to address weather-modeling uncertainty to promote higher predictability and efficiency.
- Developing and assessing systemwide performance of concepts for optimizing oceanic traffic flow.
- Determining user and service provider roles to accommodate user preferences and increase efficiency.

The Air Navigation Support subarea has several R&D needs related to designing and managing structured airspace. The TFM research focus area includes a number of activities to address these needs, as shown in the table below. Major elements of the applicable milestones include:

- Developing aggregate models for traffic flow under nominal and off-nominal conditions.
- Employing probabilistic and stochastic methods for flow management to address uncertainties in weather prediction.
- Developing and testing Evaluator concepts to increase efficiency under all weather conditions.
- Expanding Traffic Flow Management concepts to address weather-modeling uncertainty to promote higher predictability and efficiency.
- Determining user and service provider roles to accommodate user preferences and increase efficiency.

Additional activities with application to the Weather Information Services and Safety Management functional areas include:

- Employing probabilistic and stochastic methods for flow management to address uncertainties in weather prediction.
- Developing and testing Evaluator concepts to increase efficiency under all weather conditions.
- Refining the concept of traffic complexity with respect to controllers, pilots, and varying levels of automation.

Table 2.4.4-II, below, shows the TFM milestones that address the R&D needs summarized above.

Table 2.4.4-II TFM Milestones Linked to NextGen R&D Needs

TFM Milestone	Title	Year	Applicable NextGen R&D Needs
AS.1.4.01	Develop empirical and data mining models for correlating weather and key metrics for NAS performance. The milestone will be evaluated in terms of improvements in estimating NAS delay over current methods.	2008	D-0420, D-0850, R-0570, R-0580, R-1120, R-1140
AS.1.4.02	Assess and develop aggregate models, such as network flow and linear time varying models, for traffic flow under nominal and off-nominal conditions.	2008	D-0420, D-2100, R-1140

Table 2.4.4-II (Continued) TFM Milestones Linked to NextGen R&D Needs

TFM Milestone	Title	Year	Applicable NextGen R&D Needs
AS.1.4.03	Characterize current and future ATM systems by adapting concepts from Network and Graph Theory.	2008	D-0420, R-1140
AS.1.4.04	Expand the concept of Traffic Complexity to controller, pilots and varying levels of automation.	2008	D-1690, R-1140
AS.1.4.05	Develop probabilistic and stochastic methods for flow management to address uncertainties in weather prediction. Metric used will be improvements over current deterministic methods.	2010	D-0420, D-0850, R-0570, R-0580, R-0660, R-0960, R-1140
AS.1.4.06	Develop linear/nonlinear/dynamic programming and decomposition methods for advanced traffic flow management.	2011	R-0960, R-1140
AS.2.4.01	Develop Oceanic Traffic Flow Optimization Concepts.	2008	D-0420, R-0140, R-0960, R-1120, R-1130, R-1140, R-1590
AS.2.4.02	An improved metric for airspace complexity is defined.	2009	D-0420, R-0140, R-0960, R-1120, R-1130, R-1140, R-1590
AS.2.4.03	Assess System-Wide Performance of Oceanic Traffic Flow Optimization Concepts.	2010	R-0130, D-0420, D-1700, R-0140, R-0660, R-0770, R-0960, R-1120, R-1130, R-1140, R-1590
AS.2.4.04	Update and refine Airspace Evaluator requirements for the Airspace functions of the Evaluator.	2011	D-0420, R-0130, R-0140, R-0660, R-0960, R-1120, R-1130, R-1140
AS.3.4.01	Develop Traffic Flow Management concepts at the regional and national levels for different planning intervals to increase efficiency, reduce delays, and accommodate user preferences.	2008	D-0420, D-0830, D-1090, R-0130, R-0140, R-0660, R-0960, R-1120, R-1130, R-1140
AS.3.4.02	Early Evaluator concept definition and development, including initial concept of operation focused on national and regional TFM for increasing flow management efficiency and accommodating user preferences.	2009	D-0420, D-0830, D-1090, R-0130, R-0140, R-0660, R-0960, R-1120, R-1130, R-1140
AS.3.4.03	Determine user and service provider roles to accommodate user preferences and increase efficiency.	2010	D-0420, D-0830, D-1090, D-1710, R-0130, R-0140, R-0660, R-0960, R-1120, R-1130, R-1140
AS.3.4.04	Expand Traffic Flow Management concepts to address weather-modeling uncertainty to promote higher predictability and efficiency.	2010	D-0420, R-0570, R-0580, D-0830, D-1090, R-0140, R-0660, R-0960, R-1120, R-1130, R-1140
AS.3.4.05	Assess representative concepts for NextGen using system-wide models, and generate capacity, delay and predictability metrics.	2010	D-0420, D-1090, R-0140, R-0570, R-0660, R-0960, R-1120, R-1130, R-1140,D-1700
AS.3.4.06	Simulation assessment of advanced TFM concepts.	2011	D-0420, D-1090, R-0660, R-0960, R-1120, R-1130, R-1140

Table 2.4.4-II (Continued) TFM Milestones Linked to NextGen R&D Needs

TFM Milestone	Title	Year	Applicable NextGen R&D Needs
AS.4.4.01	Develop and test Evaluator concepts for advanced Traffic Flow Management to accommodate user preferences, reduce delays, and increase efficiency under all-weather conditions.	2011	R-0570, R-0580, R-0960, R-1120, R-1130, R-1140

2.4.5 Separation Assurance (SA)

SA Description

SA provides trajectory-based technologies and human/machine operating concepts that could safely support a substantial increase in capacity under nominal and failure-recovery operations, with airspace-user preference and with favorable cost/benefit ratios. This includes activities to (1) assess the SA performance and characteristics of different levels of air/ground and human/automation functional allocation; (2) develop automated conflict detection and resolution algorithms, trajectory analysis methods, and system design characteristics that together ensure safe and efficient resolution trajectories for nearly 100 percent of conflict encounters under widely varying traffic conditions, uncertainties (e.g., surveillance, weather, pilot intent, failures), and increased traffic density; (3) develop operating concepts and human-machine interface characteristics to ensure that controllers and pilots can maintain awareness of automatic separation assurance functions, simultaneously interact with semi-automatic separation assurance functions, and safely intervene in the event of unexpected conditions or component failures; (4) identify and analyze component (air and ground) failure and recovery modes to ensure timely failure detection and graceful recovery; and (5) explore the interaction of automated separation assurance with hazardous, uncertain weather and TFM automation.

Separation Assurance research comprises three initiatives: (a) Automated Separation Assurance Technology, (b) Human/Automation Operating Concepts, and (c) System Safety and Failure Recovery Analysis. Automated Separation Assurance Technology focuses on the development of automatic conflict detection and resolution algorithms, trajectory analysis methods, and system architectural characteristics that together result in automated resolution trajectories that are safe, efficient, and robust under the wide variety of traffic conditions in the NAS. Human/Automation Operating Concepts focuses on analyses of cognitive workload, situation awareness, and performance under varying concepts of operations for service-provider-based separation assurance and roles and responsibilities of controllers and pilots. These analyses are validated through a series of human-in-the-loop simulations of increasing complexity and fidelity. System Safety and Failure Recovery Analysis focuses on the identification of component failure and recovery modes for automated SA methods, including missed-conflict alerts, datalink failure, primary trajectory server failure, false read-back, human operator mistakes, and other factors.

Six NRA research subtopics support SA:

- Integrating Collision Avoidance and Tactical Air Traffic Control Tools – Develops a modeling framework to incorporate different classes of collision avoidance and separation assurance technologies, analyzes the interaction among techniques from the different classes, designs operational concepts to ensure safety of ATM when switching between different schemes, and develops test and evaluation strategies for these operational concepts.

- Analysis and Development of Strategic and Tactical Separation Assurance Algorithms – Reviews the completeness and robustness of safety evaluation algorithms, the extension of the "safe zone" concept, and the incorporation of arrival constraints.
- Concepts and Algorithms for Automated Separation Assurance – Includes the design of a centralized algorithm for en route airspace, analysis of distributed air-to-air resolution concepts, and integrated conflict resolution and air traffic management concepts.
- Metrics for Operator Situation Awareness, Workload, and Performance in Automated Separation Assurance Systems – Develops tools and methods for evaluating NextGen ATM concepts, characterizes individual and shared situation awareness in advanced NextGen systems, and supports program capability for human-in-the-loop simulations of NextGen concepts and evaluations of situation awareness, workload, and performance.
- Conduct Safety Analysis of the Separation Assurance Function in Today's National Airspace System (NAS) – Applies accepted safety and risk-analysis techniques (e.g., hazard analysis, failure modes and effects analysis, and fault tree analysis) to current-day operations in the NAS to establish failure-probability benchmarks for separation assurance in today's environment.
- Human-in-the-Loop Experiments to Probe the Limits of Human Performance and Reliability in a Backup Role for Automated Separation Assurance – The objective of this research activity is to probe the threshold at which humans are no longer able to function as reliable backups to separation-assurance automation.

SA Supported R&D Needs

Six NextGen functional areas or subareas call for SA research and development activities: Air Navigation Operations, Air Navigation Support, Flight Operations and Support, Weather Information Services, Safety Management, and Environmental Management Framework. Key components of the automated SA system will be modeled using automated software engineering tools and driven by safety-focused simulation scenarios to uncover conditions that would not be found by traditional simulations.

Specific requirements in the Air Navigation Operations subarea include, among others, the development of protocols to negotiate trajectories for the aircraft and ground information architectures (D-0830), traffic spacing alternatives in en route airspace (R-1620), requirements for optimizing flight profiles with reduced separation in oceanic airspace (R-1590), and research on airborne spacing and performance-based trajectories for airborne merging and spacing capabilities (R-0500, R-0640, R-0370). SA Air Navigation Operations research also complements research in other RFAs on the need for ground and aircraft architectures to meet the capacity and safety requirements for NextGen (R-0510) and options for automated separation (R-0530).

Air Navigation Support activities include applied research for an initial set of NextGen methodologies to translate probabilistic weather information into safety and efficiency impacts and research on the use of 4D trajectories in clearances and flight plans for flight management systems (R-0570, D-0140). There is also a need for research regarding traffic management initiatives for developing options for flight operators, including automation-assisted collaboration (R-0670, R-0130), understanding how flight operators and the ANSP negotiate objectives and trajectory preferences to balance priorities (R-1120), and applied research on automated integration of weather, environmental, aeronautical, security, and emergency information and research on demand and capacity information to support an alternative selection and policy decision for tailored information services to meet specific needs (R-0660).

The Flight Operations and Support subarea is supported by the completion of research on priorities for aircraft capabilities (R0040).

Weather Information Services R&D needs addressed by SA include the development of the first generation of probabilistic weather forecasts (R-0580) and development of a virtual four-dimensional weather information system that provides information tailored to ATM procedures, including routine and real-time hazardous-weather information (D-0850). R&D need D-1690 calls for the development of human and system performance models that accurately capture human variability and human error in highly automated NextGen systems.

Safety Management R&D needs addressed by SA include development of human and system performance models, development of system risk assessment and management models, and research on risk-reducing systems interfaces, procedures, and training to reduce human error (D-1700, D-1710, D1690).

Environmental Management Framework research required from this RFA include the development of aircraft operational control technologies and procedures, including surface movement and arrival, departure, and en route procedures that reduce noise, impact on local air quality, and potential for greenhouse gas emissions (D-1730, R-1340).

Table 2.4.5-I, below, presents the NextGen R&D needs and associated OIs that are addressed by SA research activities.

Table 2.4.5-I NextGen R&D Needs Addressed by SA

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-0330	Complete development of aircraft-based precision approach capability to support an implementation decision for aircraft-based approach and landing with performance similar to CAT II/III ground-based landing guidance systems.	2011	OI-0317: Severe Weather Airport Access
D-0830	Complete development of protocols to negotiate trajectories for supporting an implementation decision on the aircraft and ground information architectures.	2010	OI-0302:Initial Collaborative In-flight Rerouting OI-0303: Improved Collaborative Traffic Management Initiatives OI-0306: Automation-Assisted Flight Plan Negotiation
D-0850	Complete development of a virtual, authoritative, net-centric four-dimensional weather information system that provides information tailored to ATM procedures, including routine (diagnostics and forecasts) and real-time, hazardous weather information to support an implementation decision on the network-enabled 4-D Weather Cube.	2013	OI-2020: Net-Enabled Common Weather Information - Level 1 Initial Capability

Table 2.4.5-I (Continued) NextGen R&D Needs Addressed by SA

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-1690	Complete development of human-system performance models that accurately capture human variability and human error in highly automated NextGen systems to support applied research on high-level roles and responsibilities of human operators and automation in NextGen systems.	2011	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-1700	Complete development of system risk assessment and management models to applied research on the allocation of capabilities across flight operator and ANSP automation.	2012	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-1710	Complete applied research on risk-reducing systems interfaces, procedures, and training to reduce human error and complement the development of automation procedures for the range of NextGen stakeholders.	2015	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-1730	Complete development of aircraft operational control technologies and operational approaches to enable maximum use by the commercial fleet of air terminal and air space operational procedures that reduce noise, local air quality impact, and greenhouse gas emissions.	2013	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-2100	Complete development of methods for verification and validation of complex systems to support alternative NextGen risk assessment and certification decisions.	2013	(None identified in the IWP)
R-0040	Complete applied research on aircraft capability priorities for NextGen through 2015 to support alternative selection and policy for standards development and certification.	2009	OI-0334: Independent Parallel or Converging Approaches in IMC OI-0335: Dependent Multiple Approaches in IMC OI-0338: Efficient Metroplex Merging and Spacing OI-0343: Reduced Separation - High Density En Route, 3-mi. OI-0362: Self-Separation - Self-Separation Airspace OI-0363: Delegated Separation - Complex Procedures

Table 2.4.5-I (Continued) NextGen R&D Needs Addressed by SA

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0130	Complete applied research on automation-assisted collaboration capabilities to support an alternative selection for further development and policy decision on the range of stakeholder participation in the collaboration process.	2010	OI-0306: Automation-Assisted Flight Plan Negotiation
R-0140	Complete initial applied research on the use of 4DT in clearances and flight plans to support an alternatives selection decision for further development and incorporation into future flight planning systems, ATM automation, and aircraft flight management systems.	2010	OI-0306: Automation-Assisted Flight Plan Negotiation
R-0370	Complete applied research on traffic spacing management (e.g., complementary time-based metering, management by 4DT, and sequence-based, pair-wise spacing) for transition, arrival, and departure operations to support alternative selection and policy decisions on high-throughput delivery of aircraft to the runway threshold and high-throughput departure operations.	2011	OI-0326: Airborne Merging and Spacing - Single Runway OI-0329: Airborne Merging and Spacing with CDA OI-0330: Time-Based and Metered Routes with CDA
R-0500	Complete applied research on options for procedures, standards specification, decision-support aids, and displays to support an alternative selection to enable variable separation standards based on performance levels in all airspace.	2012	OI-0329: Airborne Merging and Spacing with CDA OI-0343: Reduced Separation - High Density En Route, 3-mi.
R-0510	Complete applied research on the ground and aircraft architecture (e.g., developing models to explore the trade space) that can scale to meet three times airspace capacity and safety requirements to support refinement of the NextGen separation management architecture.	2012	OI-0353: Reduced Oceanic Separation - Altitude Change Pair-wise Maneuver OI-0356: Delegated Separation - Pair-wise Maneuvers OI-0359: Delegated Separation - Oceanic
R-0530	Complete applied research on ground and aircraft automated separation management options to guide the selection of technology and procedures development for TBO in performance-based airspace.	2012	OI-0355: En Route Airborne Merging and Spacing OI-0362: Self-Separation - Self-Separation Airspace OI-0363: Delegated Separation - Complex Procedures

Table 2.4.5-I (Continued) NextGen R&D Needs Addressed by SA

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0570	Complete applied research for an initial set of NextGen methodologies for translating probabilistic weather information into safety and efficiency impacts, as well as a capability to evaluate the derived operational information improvement.	2012	OI-0303: Improved Collaborative Traffic Management Initiatives OI-2010: Net-Enabled Common Weather Information Infrastructure
R-0580	Complete development of the first generation of probabilistic weather forecasts (e.g., convective and winter storms, icing, turbulence, ceiling, and visibility) to support interagency implementation decisions.	2012	OI-2010: Net-Enabled Common Weather Information Infrastructure OI-2020: Net-Enabled Common Weather Information - Level 1 Initial Capability
R-0640	Complete applied research on performance-based trajectories through transition airspace to support an alternative selection to maximize metroplex throughput.	2012	OI-0333: Airborne Merging and Spacing for Multiple Runways OI-0338: Airborne Merging and Spacing for Metroplex
R-0660	Complete applied research on automated integration of weather, environmental, aeronautical, security, and emergency information and on demand and capacity information to support an alternative selection and policy decision for tailored information services to meet specific needs.	2012	OI-0303: Improved Collaborative Traffic Management Initiatives
R-0670	Complete applied research regarding the applicability of “control by points” traffic management initiatives to support an alternatives selection decision for developing options for flight operators to manage flights within the context of time-based control points.	2012	OI-0306: Automation-Assisted Flight Plan Negotiation
R-1120	Complete applied research on collaborative automated flight and flow evaluation and resolution capabilities to support an alternative selection on how flight operators and ANSP negotiate objectives and trajectory preferences to balance priorities, including roles and responsibilities.	2014	OI-0306: Automation-Assisted Flight Plan Negotiation
R-1340	Complete development of aircraft surface movement, arrival and departure, and en route procedures to maintain throughput while reducing environmental impacts to support an implementation decision on procedures and associated technologies by air navigation service providers and flight operators.	2015	OI-6020: Implement EMS Framework - Level 2

Table 2.4.5-I (Continued) NextGen R&D Needs Addressed by SA

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-1590	Complete applied research on requirements for optimizing flight profiles (e.g., ground- and aircraft-based solutions) to support an alternatives selection for altitude changes and co-altitude pair-wise maneuvers at reduced separation in oceanic airspace.	2013	OI-0353: Reduced Oceanic Separation - Altitude Change Pair-wise Maneuvers OI-0354: Reduced Oceanic Separation - Altitude Pair-wise Maneuvers OI-0356: Delegated Separation - Pair-wise Maneuvers
R-1620	Complete applied research on initial traffic spacing management alternatives to support an alternative selection on trajectory management, merging, spacing, and metering in congested en route airspace.	2011	(None identified in the IWP)
R-2090	Complete applied research regarding expanded traffic spacing management alternatives to support an alternative selection on trajectory management, merging, spacing, and metering in congested en route airspace.	2015	(None identified in the IWP)

Alignment of SA Milestones with R&D Needs

The three SA initiatives (Automated Separation Assurance Technology, Human/Automation Operating Concepts, and System Safety and Failure Recovery Analysis) conduct the research needed to accomplish the goals set for NextGen. The overall goal is to identify trajectory-based technologies and human-machine operating concepts that could support a substantial increase in capacity with safety under nominal and failure recovery operations, with airspace-user preference and with favorable cost/benefit ratios.

The Air Navigation Operations subarea identifies several R&D needs; a sample of SA milestones that address this subarea includes:

- Identifying methods for establishing separation criteria for NextGen operations.
- Initial operating concept options for a service-provider-based separation assurance approach.
- Trajectory analysis technology for automated separation assurance, including service-provider-based time-based-metering.
- Field evaluation of trajectory analysis technology with aircraft CNS technology for automated separation assurance.

The Air Navigation Support subarea identifies several needs related to the design and configuration of airspace and the allocation of other air traffic management resources. Milestones in SA that address these needs include:

- Strategic technology for automated resolution and trajectory change.
- Investigation of traffic complexity prediction for automated separation assurance.

- Human workload, performance, and situational awareness analysis for service-provider-based separation assurance.
- Analysis of failure and recovery modes associated with a service-provider-based approach to separation assurance.
- Analysis of aircraft CNS performance as it relates to separation assurance technology.

Milestones in this RFA that address Weather Information Services R&D needs include:
- Technology for weather-related tactical advisories.
- Technology for tactical weather and traffic complexity avoidance with time-based metering constraints.

Safety Management R&D needs are addressed, in part, by the following SA research activities:
- Methods for quantifying safety level of human operators in ATM system.
- Analysis of human workload, performance, and situation awareness in higher levels of automation for service-provider-based separation assurance.
- Analysis of failure and recovery modes associated with a service-provider-based approach to separation assurance.

The following SA activities address the Environmental Management Framework functional area:
- Flight test evaluation of an airborne situation-awareness-based application
- Field evaluation of trajectory analysis technology with aircraft CNS technology for time-based metering.

Table 2.4.5-II, below, shows the SA milestones that address the R&D needs summarized above.

Table 2.4.5-II SA Milestones Linked to NextGen R&D Needs

SA Milestone	Title	Year	Applicable NextGen R&D Needs
AS.1.5.01	Methods for establishing separation criteria for NextGen operations.	2008	R-0370, R-0500, R-0530, R-0670, R-1120, R-1620
AS.1.5.02	Methodology for analysis of tactical ATC and airborne collision avoidance interaction.	2008	R-0500, R-0530, R-1620
AS.1.5.03	Analytical methods to assess system response to failure events.	2008	D-2100, R-0500, R-0530, R-1620
AS.1.5.04	Methods for quantifying safety level of human operators in ATM system.	2009	D-1690, R-0500, R-0530, R-1620
AS.1.5.05	Verification methodologies developed for analytic and rule-based heuristic approaches to SA algorithms and software.	2010	R-0530, R-1620
AS.1.5.06	Formal proof of separation assurance for oceanic applications.	2007	R-0530, R-1590, R-1620
AS.1.5.07	Recommended complexity metric.	2008	R-1620
AS.1.5.08	Mathematical safety proof for N independent aircraft.	2009	R-1620

Table 2.4.5-II (Continued) SA Milestones Linked to NextGen R&D Needs

SA Milestone	Title	Year	Applicable NextGen R&D Needs
AS.2.5.01	Strategic automated resolution and trajectory change technology.	2007	R-0140, R-0500, R-0510, R-0530, R-0670, R-1120, R-1620
AS.2.5.02	Initial operating concept options description for service-provider-based SA approach.	2007	D-1700, D-1710, R-0040, R-0140, R-0500, R-0510, R-0530, R-0670, R-1120, R-1620
AS.2.5.03	Initial service-provider-based automated separation assurance simulation.	2007	D-1700, D-1710, R-0040, R-0130, R-0140, R-0500, R-0530, R-0670, R-1120, R-1620, R-0640
AS.2.5.04	Tactical automated safety assurance trajectories.	2008	R-0140, R-0500, R-0510, R-0530, R-0670, R-1120, R-1620, R-0640
AS.2.5.05	Technology for determining weather impacts on tactical airspace operations.	2008	D-0850, R-0140, R-0500, R-0530, R-0570, R-0580, R-0670, R-1620, R-0640
AS.2.5.06	Technology for weather related tactical advisories.	2009	D-0850, R-0140, R-0530, R-0570, R-0580, R-1620, R-0640
AS.2.5.07	Analysis of aircraft CNS performance as it relates to separation assurance technology.	2009	R-0140, R-0500, R-0530, R-1120, R-1620
AS.2.5.08	Traffic complexity prediction for automated separation assurance.	2009	R-0140, R-0500, R-0530, R-0670, R-1120, R-1620
AS.2.5.09	Human workload, performance, and situation awareness analysis of higher levels of automation for service-provider-based separation assurance.	2009	D-1710, R-0130, R-0500, R-0530, R-0670, R-1120, R-1620
AS.2.5.10	Analysis of failure and recovery modes associated with service-provider-based SA approach.	2009	D-1710, R-0530, R-0670, R-1120, R-1620
AS.2.5.11	Laboratory integration of service-provider-based separation assurance, traffic flow management, and dynamic airspace technology.	2010	R-0510, R-0530, R-0670, R-1120, R-1620
AS.3.5.01	Flight test evaluation of an airborne situation awareness based application.	2007	D-0330, D-1730, R-0040, R-0140, R-0500, R-0530
AS.3.5.02	Field evaluation of trajectory analysis technology with aircraft CNS technology for time-based metering.	2007	D-0330, D-1730, R-0500, R-0530, R-0670, R-1340, R-1620
AS.3.5.03	Trajectory analysis technology for automated separation assurance.	2008	R-0140, R-0370, R-0500, R-0530, R-0670, R-1120, R-1620, R-0640
AS.3.5.04	Service-provider-based automated separation assurance simulation.	2008	R-0040, R-0130, R-0140, R-0370, R-0500, R-0530, R-0670, R-1120, R-1620, D-1710, D-0830, R-2090
AS.3.5.05	Trajectory analysis for service-provider-based automated separation assurance with time-based metering.	2009	R-0370, R-0500, R-0530, R-0670, R-1120, R-1620

Table 2.4.5-II (Continued) SA Milestones Linked to NextGen R&D Needs

SA Milestone	Title	Year	Applicable NextGen R&D Needs
AS.3.5.06	Time-based metering with service-provider-based automated separation assurance simulation.	2010	D-1710, R-0370, R-0500, R-0530, R-0670, R-1120, R-1620
AS.3.5.07	Technology for tactical weather and traffic complexity avoidance with time-based metering constraints.	2010	D-0330, R-0300, R-0500, R-0530, R-0570, R-0580, R-0660, R-0670, R-1620
AS.3.5.08	Safety assurance via light-weight formal methods and simulation.	2010	R-0500, R-0530, R-0670, R-1620
AS.3.5.09	Field evaluation of trajectory analysis technology with aircraft CNS technology for automated separation assurance.	2010	D-0330, R-0500, R-0530, R-0670, R-1120, R-1620
AS.4.5.01	Simulation analysis of service-provider-based automated separation assurance with complex traffic, metering, hazardous weather, and failure recovery.	2011	D-0830, D-0850, D-1710, R-0500, R-0510, R-0530, R-0570, R-0580, R-0670, R-1120, R-1620, R-2090

2.4.6 Airspace Super Density Operations (ASDO)

ASDO Description

ASDO addresses airspace capacity barriers resulting from human workload and responsibilities to enable high-efficiency trajectory-based operations that are robust to weather and other disturbances in super-dense and regional or metroplex airspace, all while minimizing environmental impact. This includes the requirements for the development of (1) simultaneous sequencing and deconfliction technologies necessary for trajectory management of aircraft in terminal and extended terminal airspace, (2) precision spacing and merging capabilities to reduce workload and spacing variance between aircraft in terminal and extended terminal airspace, and (3) methods for optimizing ASDO resource utilization among interconnected air portals. The four primary tasks of this effort are discussed below.

The first major task for ASDO research is the development of an expanded Concept of Operations, leveraging the NextGen ConOps and expanding it as required to support ASDO research and concept development. This effort begins with a literature survey to determine the state of the art in proposed methods for managing terminal airspace, to identify the application of weather data to improving the efficiency of the air traffic system, and to expand on current understanding of R&D to enable ASDO. Concepts for mitigating the impact of weather focus on improvements to scheduling of terminal area NAS resources and rationing of flexible resources within the ASDO concept. Rapid prototyping and fast-time simulation will be employed to assess and iteratively refine the concept of operations based on improved understanding of the fundamental issues and development of enabling technologies to address those challenges. In coordination with the ATM-Airportal Project and the JPDO, this effort will determine the initial allocation of roles and responsibilities for the aircraft operator and the ANSP, and for the human and automation in terminal airspace operations. It will also provide guidance to the JPDO on the designation of ASDO airspace and required capabilities.

The second major task is the development of sequencing and deconfliction technologies. This work advances sequencing and deconfliction methods beyond the current practices of modified first-come first-served scheduling and tactical separation service. Foundational research will lead to an understanding of the inherent uncertainty associated with execution of precision trajectories in ASDO airspace, as well as improvements in multi-objective constraint optimization for air traffic systems. Further development of these technologies through fast-time simulation will determine the control authority necessary to achieve the prescribed capacity goal and to potentially enable resource utilization schemes that enhance robustness to varied and chaotic weather. Concepts will also be developed for reducing the impact of weather forecast uncertainty on dense terminal operations.

The third major ASDO research task is the development of technologies for precision spacing and merging. This research addresses the need to reduce the level of uncertainty inherent to aircraft operations in ASDO airspace and to enable many aspects of the Equivalent Visual Operations capabilities of NextGen. Fundamental challenges to execution of precise trajectories in dense terminal airspace include extending traditional concepts and theories for precision guidance and energy management to dependent, multiple aircraft scenarios, addressing as well the human factors considerations for procedures and interfaces in nominal, off-nominal, and failure modes. These will be addressed via rapid prototype analyses of proposed tools and interfaces and part-task, as well as full mission, simulation.

The fourth area of ASDO research will focus on optimization of regional ASDO resources. ASDO will work closely with the ATM-Airportal Project to define methods for regional resource optimization that enhance regional ASDO capacity and robustness of that capacity to a variety of disturbances. This research will incorporate PBS concepts for defining terminal area airspace designations and their associated capability requirements. Foundational research includes developing methods for managing precision and nonprecision operations in the same airspace, as well as development of the concepts through detailed analyses and development of agent-based models for inclusion in system-level assessments of the ASDO concept with NAS simulation capabilities.

Five NRA subtopics support ASDO:

- Transition to Super Density Operations Capability, 2015 Timeframe – Identifies the issues and constraints that (1) dictate current practices at hub airports in busy metroplex areas regarding the use of area navigation RNAV RNP)/Continuous Descent Arrival (CDA) routes and (2) are likely to extend to mid-term (ca. 2015) operations in NextGen. This effort will characterize the impact that the introduction of mid-term NextGen concepts and capabilities will have on operations in normal conditions, and it will investigate alternative concepts for robustly coping with routine, non-normal events (e.g., weather fronts, severe weather, missed approaches, emergency landings) and other events that result in significant changes to planned schedules for landing and departing aircraft.
- Mitigation of Weather impacts in Dense Terminal Airspace – Addresses weather impacts in Super-Dense Terminal Airspaces and the optimization of super-density multi-airport terminal area systems in the presence of uncertainty.
- Metroplex Operations – Identifies the issues and constraints that dictate current practices (such as dependencies and interactions among metroplex airports) and are likely to extend to NextGen concepts, characterizes the impact that the introduction of NextGen concepts and capabilities will have on metroplex operations, and investigates alternative concepts for significantly increasing capacity in high-demand metropolitan areas.
- Interactions Between Separation Management Functions in Terminal Airspace of NextGen – Identifies the constraints on Super Density Operations (SDO) and related procedures that are due to adverse interaction with the separation assurance and collision

avoidance functions in dense terminal airspace and any changes in existing collision avoidance capabilities and separation assurance functions that may be required to enable proposed SDO capabilities.

- Determination of Air Traffic Control and Pilot Performance Parameters for Human Performance Model Development in the Transitional (Terminal Area) Airspace for NextGen – Characterizes human-system interactions for future technologies needed to enable NextGen and determines the parameters, mean values, and distributions of candidate scenarios which will be used as inputs to human performance models that will in turn be used to predict human-system performance associated with new roles and procedures for NextGen.

ASDO Supported R&D Needs

NextGen calls for new technologies that will enable significant growth at large airports and increased operations at underutilized airports. These operations need to be robust to the various business uses of the NAS, including the hub-and-spoke just-in-time service that demands high capacity, tight scheduling, and predictable operations. It must also meet the challenge of precision sequencing, merging, spacing, and deconfliction requirements while using the airspace in an environmentally friendly fashion.

The basic NextGen-related requirements for ASDO are to:

- Enable precision trajectories in dense terminal airspace
- Define processes for regional airspace resource optimization
- Achieve robustness to varied and chaotic weather conditions
- Satisfy environmental considerations while enabling NextGen traffic density.

Because of the wide range of research required, six functional areas or subareas include R&D needs addressed in ASDO: Air Navigations Operations, Air Navigation Support, Flight Operations and Support, Weather Information Services, Safety Management, and Environmental Management Framework. There is substantial overlap and interrelationship among the R&D needs and the functional areas, as is to be expected when addressing these multifaceted technical challenges.

Air Navigation Operations R&D needs are numerous and include the investigation of aircraft-based precision approach capabilities; RNAV/RNP procedures, cockpit technologies to support independent parallel and converging runway procedures; reduced and variable traffic spacing and separation, including automated separation, operations in reduced visibility; and mixed equipage operations (D-0330, R-0340, R-0930, R-0500, R-0530, D-0590, D-0870, D-0880, R-1240, R-1250, R-2090).

Air Navigation Support R&D needs span a wide range of subjects and include airspace structure, dynamic airspace, 4DT and performance-based trajectories, weather integration, traffic spacing, integrated management of arrivals, and aircraft-derived position and intent information (R-0280, R-0140, R-0410, R-0570, R-0660, R-0370, R-0380, R-0640, R-0670, R-0680, R-0770, R-1090, R-1120, D-0920, R-0930).

Flight Operations and Support calls for reaching an understanding on aircraft capability priorities (R-0040), completion of research on cockpit technologies and procedures for low-visibility operations (R-0930), and research on staffed and automated virtual towers (R-1090).

Weather Information Services needs center on the development of a four-dimensional weather information system that provides information tailored to ATM procedures, and on development of the first generation of probabilistic weather forecasts (R-0580, D-0850).

R&D needs related to Safety Management include research and development of system risk assessment and management models and research on risk-reducing systems interfaces, procedures, and training to reduce human error (D-1700, D-1710).

Environmental Management Framework needs include the investigation of operational approaches that reduce noise, impact on local air quality, and potential for greenhouse gas emissions (D-1730).

Table 2.4.6-I, below, presents the NextGen R&D needs and associated OIs that are addressed by ASDO research activities.

Table 2.4.6-I NextGen R&D Needs Addressed by ASDO

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-0330	Complete development of aircraft-based precision approach capability to support an implementation decision for aircraft-based approach and landing with performance similar to CAT II/III ground-based landing guidance systems.	2011	OI-0317: Severe Weather Airport Access
D-0850	Complete development of a virtual, authoritative, net-centric four-dimensional weather information system that provides information tailored to ATM procedures, including routine (diagnostics and forecasts) and real-time, hazardous weather information to support an implementation decision on the network-enabled 4-D Weather Cube.	2013	OI-2020: Net-Enabled Common Weather Information - Level 1 Initial Capability
D-0870	Complete development of mixed equipage trajectory-based routes (e.g., RNAV/RNP) and advanced CDA operations to support an implementation decision for flexible trajectory-based routing between cruise and the top 100 airports.	2013	OI-0311: Enhance Arrival/Departure Routing and Access OI-0329: Airborne Merging and Spacing with CDA
D-0880	Complete development of limited visibility operations to support implementation decisions for terminal and surface operations.	2013	OI-0321:Surface Management - Level 2 Datalink/Departures OI-0322: Low-Visibility Surface Operations

Table 2.4.6-I (Continued) NextGen R&D Needs Addressed by ASDO

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-0920	Complete development of traffic spacing management components to support an implementation decision for high-throughput delivery of aircraft to the runway threshold and high-throughput departure operations.	2013	OI-0326: Airborne Merging and Spacing - Single Runway OI-0329: Airborne Merging and Spacing with CDA OI-0330: Time-Based and Metered Routes with CDA
D-1090	Complete development of limited dynamic reconfiguration of arrival and departure airspace to support an implementation decision on dynamic allocation of air traffic management personnel and facilities to match traffic flows.	2014	OI-0337: Flow Corridors - Level 1 Static
D-1250	Complete development of safe taxi operations in low visibility conditions to support an implementation decision on surface operations in near all-weather conditions.	2015	OI-0340: Near-Zero-Visibility Surface Operations
D-1700	Complete development of system risk assessment and management models to applied research on the allocation of capabilities across flight operator and ANSP automation.	2012	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures
D-1710	Complete applied research on risk-reducing systems interfaces, procedures, and training to reduce human error and complement the development of automation procedures for the range of NextGen stakeholders.	2015	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-1730	Complete development of aircraft operational control technologies and operational approaches to enable maximum use by the commercial fleet of air terminal and air space operational procedures that reduce noise, local air quality impact, and greenhouse gas emissions.	2013	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only OI-6005: Environmentally and Energy Favorable En Route Operations - Level 1

Table 2.4.6-I (Continued) NextGen R&D Needs Addressed by ASDO

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0040	Complete applied research on aircraft capability priorities for NextGen through 2015 to support alternative selection and policy for standards development and certification.	2009	OI-0334: Independent Parallel or Converging Approaches in IMC OI-0335: Dependent Multiple Approaches in IMC OI-0338: Efficient Metroplex Merging and Spacing OI-0343: Reduced Separation - High Density En Route, 3-mi. OI-0362: Self-Separation - Self-Separation Airspace OI-0363: Delegated Separation - Complex Procedures
R-0140	Complete initial applied research on the use of 4DT in clearances and flight plans to support an alternatives selection decision for further development and incorporation into future flight planning systems, ATM automation, and aircraft flight management systems.	2010	OI-0306: Automation-Assisted Flight Plan Negotiation
R-0280	Complete applied research on airspace structure elements to reduce controller training time, to support an alternative selection on the airspace elements and related controller tasks.	2011	OI-0307: Airspace Reconfiguration - Level 2 - Limited Dynamic Arrival/Departure
R-0340	Complete development of three-dimensional RNAV/RNP procedures for implementation decision.	2011	(None identified in the IWP)
R-0370	Complete applied research on traffic spacing management (e.g., complementary time-based metering, management by 4DT, and sequence-based, pair-wise spacing) for transition, arrival, and departure operations to support alternative selection and policy decisions on high-throughput delivery of aircraft to the runway threshold and high-throughput departure operations.	2011	OI-0326: Airborne Merging and Spacing - Single Runway OI-0329: Airborne Merging and Spacing with CDA OI-0330: Time-Based and Metered Routes with CDA
R-0380	Complete applied research on aircraft-derived position and intent information to support the definition of initial data exchange requirements for advanced application in high density terminal areas.	2011	OI-0326: Airborne Merging and Spacing - Single Runway

Table 2.4.6-I (Continued) NextGen R&D Needs Addressed by ASDO

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0410	Complete applied research of integrated management of arrival and departure flows with surface operations to support an implementation decision.	2011	OI-0331: Integrated Arrival/Departure and Surface Traffic Management OI-0339: Integrated Arrival/Departure and Surface Traffic Management for Metroplex
R-0500	Complete applied research on options for procedures, standards specification, decision-support aids, and displays to support an alternative selection to enable variable separation standards based on performance levels in all airspace.	2012	OI-0329: Airborne Merging and Spacing with CDA OI-0343: Reduced Separation - High Density En Route, 3-mi.
R-0530	Complete applied research on ground and aircraft automated separation management options to guide the selection of technology and procedures development for TBO in performance-based airspace.	2012	OI-0355: En Route Airborne Merging and Spacing OI-0362: Self-Separation - Self-Separation Airspace OI-0363: Delegated Separation - Complex Procedures
R-0570	Complete applied research for an initial set of NextGen methodologies for translating probabilistic weather information into safety and efficiency impacts, as well as a capability to evaluate the derived operational information improvement.	2012	OI-0303: Improved Collaborative Traffic Management Initiatives OI-2010: Net-Enabled Common Weather Information Infrastructure
R-0580	Complete development of the first generation of probabilistic weather forecasts (e.g., convective and winter storms, icing, turbulence, ceiling, and visibility) to support interagency implementation decisions.	2012	OI-2010: Net-Enabled Common Weather Information Infrastructure OI-2020: Net-Enabled Common Weather Information - Level 1 Initial Capability
R-0590	Complete applied research on operational concepts for reducing visibility and cloud clearance requirements for VFR flight, for an alternative selection of increased utility of VFR operations.	2012	OI-0316: Enhanced Visual Separation for Successive Approaches

Table 2.4.6-I (Continued) NextGen R&D Needs Addressed by ASDO

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0640	Complete applied research on performance-based trajectories through transition airspace to support an alternative selection to maximize metroplex throughput.	2012	OI-0333: Airborne Merging and Spacing for Multiple Runways OI-0338: Airborne Merging and Spacing for Metroplex
R-0660	Complete applied research on automated integration of weather, environmental, aeronautical, security, and emergency information and on demand and capacity information to support an alternative selection and policy decision for tailored information services to meet specific needs.	2012	OI-0303: Improved Collaborative Traffic Management Initiatives
R-0670	Complete applied research regarding the applicability of “control by points” traffic management initiatives to support an alternatives selection decision for developing options for flight operators to manage flights within the context of time-based control points.	2012	OI-0306: Automation-Assisted Flight Plan Negotiation
R-0680	Complete applied research on methodologies for the dynamic allocation of NAS resources (including use of airspace for military and other national missions) and ANSP resources to support a policy decision for how services and access will be equitably and dynamically distributed in a performance-based operation.	2012	OI-0337: Flow Corridors - Level 1 Static OI-0365: SUA Airspace Management - Level 2 Improved Coordination OI-0367: Airspace Reconfiguration Level 3 - Dynamic En Route
R-0770	Complete applied research on dynamically allocate demand to facilities to support an alternative selection to increase productivity, maintain capacity, and manage workload.	2012	OI-0307: Airspace Reconfiguration - Level 2 - Limited Dynamic Arrival/Departure OI-0342: Airspace Reconfiguration - Level 4 Dynamic Arrival/Departure, OI-0365: SUA Airspace Management - Level 2 Improved Coordination
R-0930	Complete applied research on cockpit technologies and procedures to support an alternative selection for independent parallel and converging runway procedures in low visibility.	2013	OI-0334: Independent Parallel or Converging Approaches in IMC

Table 2.4.6-I (Continued) NextGen R&D Needs Addressed by ASDO

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-1040	Complete applied research on staffed and automated virtual tower options and other mechanisms to support selection of alternatives for expanding service to more airports.	2013	OI-0313: Virtual Towers - Level 1 Sequencing, Separation, and Spacing OI-0315: Virtual Towers - Level 2 Sequencing/ Separation/ Spacing/Surface Management
R-1120	Complete applied research on collaborative automated flight and flow evaluation and resolution capabilities to support an alternative selection on how flight operators and ANSP negotiate objectives and trajectory preferences to balance priorities, including roles and responsibilities.	2014	OI-0306: Automation-Assisted Flight Plan Negotiation
R-1240	Complete applied research on technologies and procedures to support an alternative selection for very closely spaced parallel runway procedures in low visibility.	2015	OI-0335: Dependent Multiple Approaches in IMC
R-1340	Complete development of aircraft surface movement, arrival and departure, and en route procedures to maintain throughput while reducing environmental impacts to support an implementation decision on procedures and associated technologies by air navigation service providers and flight operators.	2015	OI-6020: Implement EMS Framework - Level 2
R-2090	Complete applied research regarding expanded traffic spacing management alternatives to support an alternative selection on trajectory management, merging, spacing, and metering in congested en route airspace.	2015	(None identified in the IWP)

Alignment of ASDO Milestones with R&D Needs

ASDO research, as reflected in its milestones, focuses on the needs outlined above. The activities described are robust, often addressing R&D needs spanning multiple functional areas.

In the Trajectory-Based and Performance-Based Operations and Support functional area, which encompasses the Air Navigation Operations, Air Navigation Support, and Flight Operations and Support subareas, applicable ASDO efforts are:

- Develop and refine ASDO concept definition
- Develop procedures and technologies for initial ASDO concept of operations
- Develop an initial sequencing and deconfliction algorithm
- Identify initial algorithm, procedures, and information requirements for merging and spacing technology
- Identify user information and decision support needs for sequencing, merging, and spacing
- Develop guidance methods for energy management for efficient ASDO operations.

The Weather Information Services functional area is addressed by ASDO work to investigate scheduling and rationing algorithms for weather-impacted NAS resources.

Research activities applicable to the Safety Management functional area include:

- Procedures and technologies for an initial ASDO concept of operations
- Definition of regional resource planning and development of an initial concept for regional resource utilization and allocation.

R&D needs in the Environmental Management Framework functional area are addressed by:

- Flight validation of Low Noise Guidance
- Development of advanced guidance methods for energy management for efficient ASDO operations.

Table 2.4.6-II, below, shows the ASDO milestones that address the R&D needs summarized above.

Table 2.4.6-II ASDO Milestones Linked to NextGen R&D Needs

ASDO Milestone	Title	Year	Applicable NextGen R&D Needs
AS.1.6.01	Characterize and quantify the uncertainty impact of ASDO procedures.	2008	D-0880, D-0920, R-0140, R-0340, R-0370, R-0500, R-0530, R-0590, R-0670, R-1240, R-2090
AS.1.6.02	Investigate scheduling and rationing algorithms for weather impacted NAS resources.	2009	D-0850, D-0880, D-0920, R-0370, R-0500, R-0530, R-0570, R-0580, R-0590, R-2090
AS.1.6.03	Develop advanced guidance methods for energy management for efficient ASDO operations.	2010	D-0880, D-0920, D-1730, R-0370, R-0380, R-0500, R-0530, R-0590, R-0930, R-1240, R-2090
AS.1.6.04	Explore Innovative Guidance and Control Methods for the Super Density terminal environment.	2010	D-0880, D-0920, R-0370, R-0380, R-0500, R-0530, R-0590, R-0930, R-1240, R-2090
AS.2.6.01	Flight validation of Low Noise Guidance (LNG).	2007	D-0870, D-0880, D-0920, D-1730, R-0040, R-0340, R-0660, R-0930, R-1040, R-1340
AS.2.6.02	Support for initial algorithm, procedures and information requirements for merging and spacing technology.	2007	D-0870, D-0880, D-0920, D-1710, D-1730, R-0040, R-0340, R-0370, R-0380, R-0410, R-0500, R-0530, R-0590, R-0660, R-0670, R-0930, R-1120, R-1340, R-2090, R-0280
AS.2.6.03	Initial Sequencing and Deconfliction Algorithm.	2008	D-0870, D-0880, D-0920, D-1730, R-0340, R-0370, R-0410, R-0500, R-0530, R-0590, R-0640, R-0660, R-1040, R-1340, R-2090

Table 2.4.6-II (Continued) ASDO Milestones Linked to NextGen R&D Needs

ASDO Milestone	Title	Year	Applicable NextGen R&D Needs
AS.2.6.04	Develop method for airborne maneuvering within established limits to make gross corrections to inter-aircraft spacing.	2009	D-0330, D-0870, D-0880, D-0920, R-0040, R-0340, R-0380, R-0500, R-0530, R-0590, R-2090
AS.2.6.05	Identify user information and decision support needs for sequencing, merging and spacing.	2009	D-0330, D-0870, D-0880, D-0920, R-0040, R-0340, R-0370, R-0380, R-0500, R-0530, R-0590, R-0670, R-1120, R-2090, R-0280
AS.2.6.06	Definition of data exchange requirements for Resource Scheduling Optimization.	2009	D-0870, D-0880, D-0920, R-0340, R-0370, R-0530, R-0590, R-0670, R-0680, R-0770, R-0930, R-1120
AS.2.6.07	Procedures and technologies for initial ASDO concept of operations.	2010	D-0870, D-0880, D-0920, D-1700, D-1710, R-0340, R-0370, R-0380, R-0500, R-0530, R-0590, R-0660, R-0670, R-0930, R-1120, R-1240, R-1340, R-2090
AS.2.6.08	Develop enhanced FMS guidance and control algorithms to enable ASDO.	2011	D-0870, D-1710, D-1730, R-0370, R-0380, R-0410, R-0500, R-0530, R-0590, R-0660, R-0930, R-1120, R-1240, R-1340, R-2090
AS.3.6.01	ASDO initial concept definition.	2007	D-0330, D-0870, D-0880, D-0920, D-1250, D-1700, D-1710, D-1730, R-0040, R-0340, R-0370, R-0380, R-0410, R-0500, R-0530, R-0590, R-0640, R-0660, R-0670, R-0930, R-1040, R-1120, R-1240, R-1340, R-2090
AS.3.6.02	Refine algorithms, procedures and information requirements for third phase of FAA's planned Merging and Spacing operations.	2008	D-0330, D-0870, D-0880, D-0920, D-1730, R-0040, R-0340, R-0370, R-0380, R-0410, R-0500, R-0530, R-0660, R-0670, R-0930, R-1240, R-1340, R-2090
AS.3.6.03	Development of advanced controller decision support tools (DST) to support ASDO.	2010	D-0880, D-0920, D-1730, R-0370, R-0410, R-0500, R-0530, R-0590, R-0640, R-0660, R-0670, R-1040, R-1120, R-1340, R-2090
AS.3.6.04	Regional Resource Planning Definition.	2010	D-1090, D-1710, R-0680, R-0770, R-1120, R-1340, R-0280
AS.3.6.05	Refined Sequencing and Deconfliction Algorithm.	2011	D-0880, D-0920, D-1730, R-0370, R-0500, R-0590, R-0640, R-0660, R-1040, R-1340

Table 2.4.6-II (Continued) ASDO Milestones Linked to NextGen R&D Needs

ASDO Milestone	Title	Year	Applicable NextGen R&D Needs
AS.3.6.06	Initial Regional Resource Utilization and Allocation Concept.	2011	D-1090, D-1710, R-0680, R-0770, R-1120, R-1340, R-0280
AS.4.6.01	ASDO refined concept definition.	2011	D-0870, D-0880, D-0920, D-1250, D-1700, D-1710, D-1730, R-0370, R-0380, R-0410, R-0500, R-0570, R-0580, R-0590, R-0640, R-0670, R-1120, R-1240, R-1340, R-2090

2.4.7 System-Level Design, Analysis and Simulation Tools (SLDAST)

SLDAST Description

SLDAST develops and applies system design and analysis methods and simulation tools to produce and assess integrated comprehensive design alternatives. This includes the requirements to (1) generate relevant scenarios (nominal and off-nominal) for assessment, (2) explore relevant system-level tradespace (e.g., sort out the functional and temporal distribution of authority and responsibility between automation and human and between air and ground), (3) conduct system-level safety analysis, and (4) define and maintain a database of common analysis information (e.g., metrics, traffic demand forecasts, assumptions, weather characteristics).

This crosscutting RFA focuses on system-level design and analysis and systemwide simulation requirements, providing overarching views of ATM-Airspace Project technology and conceptual research thrusts. Design, analysis, and simulation are closely tied interactive activities; each depends on and supports the others. System design is the process of designing a system that encompasses all the relevant technologies and concepts emanating from the other technical fields. System analysis consists of a suite of studies posed to answer key questions emanating from system design. The answers will guide design decisions and influence the final design of the system. System simulation is the process of integrating models of the technologies flowing out of the other NextGen technologies, including the ATM-Airportal project, into a common simulation platform, where possible, or using them in combination to view multiple design and stakeholder aspects. These foundational design tools will simulate NextGen in aggregation and provide detailed views of the technical components of the ATM-Airspace Project.

The following outcomes are desired from SLDAST:

- Identify an initial demonstration problem for methodology development
- Develop functional dependencies between an initial set of variables and metrics in the network domain
- Develop functional dependencies between an initial set of variables and metrics in the network and simulation domains
- Develop design optimization algorithms for simulation metrics (objectives) in terms of network domain variables
- Evaluate progress and potential for success of modeling capabilities in collaboration with NASA researchers
- Develop unique evaluation criteria for candidate technologies.

Three NRA subtopics support SLDAST:

- Modeling and Design Tools for Complex Adaptive Air Transport Networks – Develops predictive modeling capabilities and design optimization algorithms to enable the active design of practical aspects of air transport networks, such as topology, architecture, and scheduling, as well as overall emergent, complex, adaptive air transportation systems.
- Human Performance Issues in the Transition to NextGen – Identifies and prioritizes leading-edge, human-performance-related research needed to support the achievement of NextGen milestones and programmatic goals, ensuring that research related to human performance is properly integrated across all milestones. In addition, there is a focus on points of transition as advances are made toward realizing the vision of NextGen.
- Explore the Feasibility of Linking a Set of Variable Fidelity and System Scope Airspace Modeling and Simulation Tools – Initiates the development of an integrated modeling and simulation capability that will allow designers of NextGen to assess large-scale, system-level impacts of proposed elements of ATM concepts of the ATM-Airspace Project.

SLDAST Supported R&D Needs

The goal of simulation and analysis tools is to develop a common modeling approach to study the behavior and feasibility of alternative ways that control entities interact with each other and exchange information. These tools provide a means to examine control entities that span long-term strategic to near-term tactical timeframes, as well as to understand the hierarchical interactions among control entities in terms of how information and constraints are represented and employed.

As can be expected by the crosscutting nature of SLDAST, a broad range of research is required. This range includes the Air Navigation Operations, Air Navigation Support, Flight Operations and Support, Weather Information Services, Safety Management, and Environmental Management Framework functional areas and subareas, with substantial overlap and interrelationship among the R&D needs and functional areas.

Air Navigation Operations R&D needs include applied research to assess and predict the severity of aircraft wake encounters based on aircraft parameters and wake geometry to support an alternatives selection decision on dynamic wake spacing based on wake persistence and decay (R-0600); development of limited-visibility operations to support implementation decisions for terminal and surface operations (D-0880); applied research on technologies and procedures to support an alternative selection for very closely spaced parallel runway procedures in low visibility (R-1240); development of safe taxi operations in low-visibility conditions to support an implementation decision on surface operations in near-all-weather conditions (D-1250); applied research on aircraft-derived position and intent information to support the definition of initial data exchange requirements for advanced application in high density terminal areas (R-0380); applied research on aircraft-based CNS performance levels to develop requirements for self-separation (R-1600); applied research on options for procedures, standards specification, decision support aids, and displays to support an alternative selection to enable variable separation standards based on performance levels in all airspace (R-0500); applied research on the ground and aircraft architecture (e.g., developing models to explore the trade space) that can scale to meet three times the current airspace capacity and on safety requirements to support refinement of the NextGen separation management architecture (R-0510); applied research on operational concepts for reducing visibility and cloud clearance requirements for VFR flight for an alternative selection of increased utility VFR operations (R-0590); development of mixed-equipage trajectory-based routes (e.g., RNAV/RNP) and advanced CDA operations to support an implementation decision for flexible trajectory-based routing between cruise and approach at the top 100 airports (R-0870); applied research on initial management alternatives for traffic spacing to support an alternative selection on trajectory management, merging, spacing, and metering in congested en route airspace (R-1620); applied research on technologies and procedures for flow corridors to support alternatives selection on the use of flow corridors and the associated air and ground technologies (R-1630); and applied research regarding expanded management alternatives for traffic spacing to support an alternative selection on trajectory management, merging, spacing, and metering in congested en route airspace (R-2090).

Air Navigation Support R&D needs span a wide range of subjects, including applied research on integrated management of arrival and departure flows with surface operations to support an implementation decision (R-0410); development of a NAS-wide aggregate flow model to support an implementation decision on capabilities supporting common situational awareness of current and forecast congestion and mitigation options for ATM personnel, flight operators, and flight crews (D-0420); applied research on airspace structure elements to reduce controller training time, to support an alternative selection on the airspace elements and related controller tasks (R-0280); applied research for an initial set of NextGen methodologies for translating probabilistic weather information into safety and efficiency impacts and the derived operational information improvement (R-0570); applied research on traffic spacing management for transition, arrival, and departure operations to support alternative selection and policy decisions on high-throughput delivery of aircraft to the runway threshold and high-throughput departure operations (R-0370); and applied research on adaptable airspace structures, including flow corridors, to support an alternative selection of performance-based adaptable airspace structures (R-0540).

Additional Air Navigation Support R&D needs include applied research for an initial set of NextGen methodologies for translating probabilistic weather information into safety and efficiency impacts, and evaluation of the derived operational information improvement (R-0570); applied research on performance-based trajectories through transition airspace to support an alternative selection to maximize metroplex throughput (R-0640); applied research on airspace design flexibility and techniques for exploiting performance-based trajectories to support an alternative decision on safe and efficient utilization of high-density terminal airspace (R-0650); applied research on automated capacity problem detection, notification, coordination, and resolution to support an alternative selection for capacity management capabilities (R-1130); applied research regarding the applicability of “control by points” traffic management initiatives to support an alternatives selection decision for developing options for flight operators to manage flights within the context of time-based control points (R-0670); applied research on dynamic allocation of demand to facilities to support an alternative selection to increase productivity, maintain capacity, and manage workload (R-0770); completion of applied research on methodologies for the dynamic allocation of NAS resources (including use of airspace for military and other national missions) and ANSP resources to support a policy decision for how services and access will be equitably and dynamically distributed in a performance-based operation (R-0680); development of limited dynamic reconfiguration of arrival and departure airspace to support an implementation decision on dynamic allocation of air traffic management personnel and facilities to match traffic flows (D-1090); development of traffic spacing management components to support an implementation decision for high-throughput delivery of aircraft to the runway threshold and high-throughput departure operations (D-0920); and applied research on collaborative automated flight and flow evaluation and resolution capabilities to support an alternative selection on how flight operators and ANSP negotiate objectives and trajectory preferences to balance priorities, including roles and responsibilities (R-1120).

Flight Operations and Support R&D needs relevant to SLDAST address applied research on service benefits and costs for combined NextGen aircraft capabilities to support alternative selections and policies on incentives or access-based mandates for airborne capabilities through 2020, recognizing the operational diversity across commercial, military, business aviation, and general aviation operators (R-1080).

Weather Information Services R&D needs focus on the development of the first generation of probabilistic weather forecasts (e.g., convective and winter storms, icing, turbulence, ceiling, and visibility) to support interagency implementation decisions (R-0580).

R&D needs related to Safety Management include development of human-system performance models that accurately capture human variability and human error in highly automated systems (D-1690); development of system risk assessment and management models to applied research on the allocation of capabilities across flight operator and ANSP automation (D-1700); applied research on risk-reducing systems interfaces, procedures, and training to reduce human error and complement the development of automation procedures for the range of NextGen stakeholders (D-1710); applied research of methods for verification and validation of complex systems to support alternative NextGen risk assessment and certification decisions (R-1440); and development of methods for verification and validation of complex systems to support alternative NextGen risk assessment and certification decisions (D-2100).

Environmental Management Framework R&D needs include the investigation of operational approaches that reduce noise, impact on local air quality, and potential for greenhouse gas emissions, and the investigation of aircraft surface movement, arrival and departure, and en route procedures to maintain throughput while reducing environmental impacts (D-1730 and R-1340).

Table 2.4.7-I, below, presents the NextGen R&D needs and associated OIs that are addressed by SLDAST research activities.

Table 2.4.7-I NextGen R&D Needs Addressed by SLDAST

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-0420	Complete development of an NAS-wide aggregate flow model to support an implementation decision on capabilities supporting common situational awareness of current and forecast congestion and mitigation options among ATM personnel, flight operators, and flight crews.	2011	OI-0303: Improved Collaborative Traffic Management Initiatives OI-0305: Traffic Flow Management Alternatives Analysis
D-0870	Complete development of mixed equipage trajectory-based routes (e.g., RNAV/RNP) and advanced CDA operations to support an implementation decision for flexible trajectory-based routing between cruise and the top 100 airports.	2013	OI-0311: Enhance Arrival/Departure Routing and Access OI-0329: Airborne Merging and Spacing with CDA
D-0880	Complete development of limited visibility operations to support implementation decisions for terminal and surface operations.	2013	OI-0321:Surface Management - Level 2 Datalink/Departures OI-0322: Low-Visibility Surface Operations

Table 2.4.7-I (Continued) NextGen R&D Needs Addressed by SLDAST

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-0920	Complete development of traffic spacing management components to support an implementation decision for high-throughput delivery of aircraft to the runway threshold and high-throughput departure operations.	2013	OI-0326: Airborne Merging and Spacing - Single Runway OI-0329: Airborne Merging and Spacing with CDA OI-0330: Time-Based and Metered Routes with CDA
D-1090	Complete development of limited dynamic reconfiguration of arrival and departure airspace to support an implementation decision on dynamic allocation of air traffic management personnel and facilities to match traffic flows.	2014	OI-0337: Flow Corridors - Level 1 Static
D-1250	Complete development of safe taxi operations in low visibility conditions to support an implementation decision on surface operations in near all-weather conditions.	2015	OI-0340: Near-Zero-Visibility Surface Operations
D-1690	Complete development of human-system performance models that accurately capture human variability and human error in highly automated NextGen systems to support applied research on high-level roles and responsibilities of human operators and automation in NextGen systems.	2011	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-1700	Complete development of system risk assessment and management models to applied research on the allocation of capabilities across flight operator and ANSP automation.	2012	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only
D-1710	Complete applied research on risk-reducing systems interfaces, procedures, and training to reduce human error and complement the development of automation procedures for the range of NextGen stakeholders.	2015	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only

Table 2.4.7-I (Continued) NextGen R&D Needs Addressed by SLDAST

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
D-1730	Complete development of aircraft operational control technologies and operational approaches to enable maximum use by the commercial fleet of air terminal and air space operational procedures that reduce noise, local air quality impact, and greenhouse gas emissions.	2013	OI-0324: Wake-based spacing - Level 1 Static Subsequent Arrival/Departures OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only OI-6005: Environmentally and Energy Favorable En Route Operations - Level 1
D-2100	Complete development of methods for verification and validation of complex systems to support alternative NextGen risk assessment and certification decisions.	2013	(None identified in the IWP)
R-0280	Complete applied research on airspace structure elements to reduce controller training time, to support an alternative selection on the airspace elements and related controller tasks.	2011	OI-0307: Airspace Reconfiguration - Level 2 - Limited Dynamic Arrival/Departure
R-0370	Complete applied research on traffic spacing management (e.g., complementary time-based metering, management by 4DT, and sequence-based, pair-wise spacing) for transition, arrival, and departure operations to support alternative selection and policy decisions on high-throughput delivery of aircraft to the runway threshold and high-throughput departure operations.	2011	OI-0326: Airborne Merging and Spacing - Single Runway OI-0329: Airborne Merging and Spacing with CDA OI-0330: Time-Based and Metered Routes with CDA
R-0380	Complete applied research on aircraft-derived position and intent information to support the definition of initial data exchange requirements for advanced application in high density terminal areas.	2011	OI-0326: Airborne Merging and Spacing - Single Runway
R-0410	Complete applied research of integrated management of arrival and departure flows with surface operations to support an implementation decision.	2011	OI-0331: Integrated Arrival/Departure and Surface Traffic Management OI-0339: Integrated Arrival/Departure and Surface Traffic Management for Metroplex
R-0500	Complete applied research on options for procedures, standards specification, decision-support aids, and displays to support an alternative selection to enable variable separation standards based on performance levels in all airspace.	2012	OI-0329: Airborne Merging and Spacing with CDA OI-0343: Reduced Separation - High Density En Route, 3-mi.

Table 2.4.7-I (Continued) NextGen R&D Needs Addressed by SLDAST

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0510	Complete applied research on the ground and aircraft architecture (e.g., developing models to explore the trade space) that can scale to meet three times airspace capacity and safety requirements to support refinement of the NextGen separation management architecture.	2012	OI-0353: Reduced Oceanic Separation - Altitude Change Pair-wise Maneuvers OI-0356: Delegated Separation - Pair-wise Maneuvers OI-0359: Delegated Separation - Oceanic
R-0540	Complete applied research on adaptable airspace structures, including corridors, to support an alternative selection of performance-based adaptable airspace structures.	2012	OI-0351: Airspace Reconfiguration - Level 1 Limited Dynamic En Route OI-0361: Flexible Resource Allocation for Airspace Management
R-0570	Complete applied research for an initial set of NextGen methodologies for translating probabilistic weather information into safety and efficiency impacts, as well as a capability to evaluate the derived operational information improvement.	2012	OI-0303: Improved Collaborative Traffic Management Initiatives OI-2010: Net-Enabled Common Weather Information Infrastructure
R-0580	Complete development of the first generation of probabilistic weather forecasts (e.g., convective and winter storms, icing, turbulence, ceiling, and visibility) to support interagency implementation decisions.	2012	OI-2010: Net-Enabled Common Weather Information Infrastructure OI-2020: Net-Enabled Common Weather Information - Level 1 Initial Capability
R-0590	Complete applied research on operational concepts for reducing visibility and cloud clearance requirements for VFR flight, for an alternative selection of increased utility of VFR operations.	2012	OI-0316: Enhanced Visual Separation for Successive Approaches
R-0600	Complete applied research to assess and predict the severity of aircraft wake encounters based on aircraft parameters and wake geometry to support an alternatives selection decision on dynamic wake spacing based on wake persistence and decay.	2016	OI-0328: Wake-Based Spacing - Level 2 Dynamic Drift Only OI-0336: Wake-based Spacing - Level 3 Dynamic Drift and Decay
R-0640	Complete applied research on performance-based trajectories through transition airspace to support an alternative selection to maximize metroplex throughput.	2012	OI-0333: Airborne Merging and Spacing for Multiple Runways OI-0338: Airborne Merging and Spacing for Metroplex

Table 2.4.7-I (Continued) NextGen R&D Needs Addressed by SLDAST

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-0650	Complete applied research on airspace design flexibility and techniques for exploiting performance-based trajectories to support an alternative decision on safe and efficient utilization of high-density terminal airspace.	2012	OI-0338: Efficient Metroplex Merging and Spacing OI-0339: Integrated Arrival/Departure and Surface Traffic Management for Metroplex OI-0342: Airspace Reconfiguration - Level 4 Dynamic Arrival/Departure
R-0670	Complete applied research regarding the applicability of "control by points" traffic management initiatives to support an alternatives selection decision for developing options for flight operators to manage flights within the context of time-based control points.	2012	OI-0306: Automation-Assisted Flight Plan Negotiation
R-0680	Complete applied research on methodologies for the dynamic allocation of NAS resources (including use of airspace for military and other national missions) and ANSP resources to support a policy decision for how services and access will be equitably and dynamically distributed in a performance-based operation.	2012	OI-0337: Flow Corridors - Level 1 Static OI-0365: SUA Airspace Management - Level 2 Improved Coordination OI-0367: Airspace Reconfiguration Level 3 - Dynamic En Route
R-0770	Complete applied research on dynamically allocate demand to facilities to support an alternative selection to increase productivity, maintain capacity, and manage workload.	2012	OI-0307: Airspace Reconfiguration - Level 2 - Limited Dynamic Arrival/Departure OI-0342: Airspace Reconfiguration - Level 4 Dynamic Arrival/Departure OI-0365: SUA Airspace Management - Level 2 Improved Coordination
R-1080	Complete applied research on service benefits and costs for combined NextGen aircraft capabilities to support alternative selections and policies on incentives or access-based mandates for airborne capabilities through 2020, recognizing the operational diversity across commercial, military, business aviation, and general aviation operators.	2013	OI-0343: Reduced Separation - High Density En Route, 3-mi.

Table 2.4.7-I (Continued) NextGen R&D Needs Addressed by SLDAST

NextGen ID	Description of Need	Required Completion Date	Supported First-Tier OIs
R-1120	Complete applied research on collaborative automated flight and flow evaluation and resolution capabilities to support an alternative selection on how flight operators and ANSP negotiate objectives and trajectory preferences to balance priorities, including roles and responsibilities.	2014	OI-0306: Automation-Assisted Flight Plan Negotiation
R-1130	Complete applied research on automated capacity problem detection, notification, coordination, and resolution to support an alternative selection for capacity management capabilities.	2014	OI-0306: Automation-Assisted Flight Plan Negotiation
R-1240	Complete applied research on technologies and procedures to support an alternative selection for very closely spaced parallel runway procedures in low visibility.	2015	OI-0335: Dependent Multiple Approaches in IMC
R-1340	Complete development of aircraft surface movement, arrival and departure, and en route procedures to maintain throughput while reducing environmental impacts to support an implementation decision on procedures and associated technologies by air navigation service providers and flight operators.	2015	OI-6020: Implement EMS Framework - Level 2
R-1440	Complete applied research of methods for verification and validation of complex systems to support alternative NextGen risk assessment and certification decisions.	2012	OI-3004: Improved Operational Processes using the Safety Management System (SMS)
R-1600	Complete applied research on aircraft-based communications, navigation, and surveillance (CNS) performance levels to develop requirements for self-separation.	2016	OI-0359: Delegated Separation - Oceanic
R-1620	Complete applied research on initial traffic spacing management alternatives to support an alternative selection on trajectory management, merging, spacing, and metering in congested en route airspace.	2011	(None identified in the IWP)
R-1630	Complete applied research on technologies and procedures for flow corridors to support alternatives selection on the use of flow corridors and the associated air and ground technologies.	2016	OI-0361: Flexible Resource Allocation for Airspace Management OI-0368: Flow Corridors - Level 2 Dynamic
R-2090	Complete applied research regarding expanded traffic spacing management alternatives to support an alternative selection on trajectory management, merging, spacing, and metering in congested en route airspace.	2015	(None identified in the IWP)

Alignment of SLDAST Milestones with R&D Needs

SLDAST research, as reflected in its milestones, focuses directly on the needs outlined above. Befitting their crosscutting nature, SLDAST activities complement research in other RFAs and, as indicated by repeated entries in the list below, often address a number of R&D needs spanning two or more functional areas.

Research in the Air Navigation Operations subarea includes the following, all of which also support the Air Navigation Support subarea:

- Develop prognostic safety assessment methods for systems and operations
- Develop fast-time system-level simulation of NextGen technologies
- Develop prognostic safety assessment methods for systems and operations
- Develop an initial system-level concept of operations, leveraging the NextGen ConOps and expanding development as required to support Airspace Systems Program (ATM-Airspace and ATM-Airportal) research and concept development.

SLDAST research topics applicable to the Air Navigation Support subarea include those listed under Air Navigation Operations and two additional thrusts:

- Develop individual agent-based models of NextGen technologies
- Develop a refined system-level concept of operations based on results of modeling, safety analysis, cost-benefits analysis, and human-in-the-loop simulations.

Flight Operations and Support research in SLDAST includes:

- Conduct objective analysis of service provider and aircraft operator separation assurance methods.

SLDAST work addressing R&D needs in the Weather Information Services functional area will develop a refined system-level concept of operations based on results of modeling, safety analysis, cost-benefits analysis, and human-in-the-loop simulations.

Safety Management functional area research activities include the following:

- Develop method for modeling human workload in fast-time simulations, and validate models against workload measurements.
- Conduct objective analysis of service provider and aircraft operator separation assurance methods.
- Develop a refined system-level concept of operations based on results of modeling, safety analysis, cost-benefits analysis, and human-in-the-loop simulations.

R&D needs in the Environmental Management Framework functional area are addressed by the following activity:

- Develop an initial system-level concept of operations, leveraging the NextGen ConOps and expanding development as required to support Airspace Systems Program research and concept development.

Table 2.4.7-II, which follows, shows the SLDAST milestones that address the R&D needs summarized above.

Table 2.4.7-II SLDAST Milestones Linked to NextGen R&D Needs

SLDAST Milestone	Title	Year	Applicable NextGen R&D Needs
AS.1.7.01	Develop initial system-level ConOps. Leverage JPDO NextGen ConOps, and expand development as required, to support Airspace Systems Program (Airspace & Airportal) research, and concept development.	2007	R-0540, R-0640, R-0650, R-0680, R-0770, R-1340, R-1600, R-1620, R-1630
AS.1.7.02	Research game-theoretic concerns with distributed control in safety critical scenarios.	2008	R-0500, R-0530, R-0680, R-1120, R-1590, R-1620, D-0920, D-1250, D-1690, D-2100.
AS.1.7.03	Develop individual agent-based models of NextGen technologies.	2008	D-0420
AS.1.7.04	Develop interim system-level concept of operations to accommodate 3x demand based on results of studies and identified gaps.	2009	R-0510, R-0540, R-0570, R-0580, R-0640, R-0650, R-0680, R-1080, R-1440, R-1600, R-1620, D-1700.
AS.1.7.05	Develop approach for System Validation and Certification methodology.	2010	D-2100, R-1440
AS.1.7.06	Define minimal constraint/data for systemic control.	2010	R-0130, R-0370, R-0530, R-0570, R-0960, R-1120, R-1130, R-1700
AS.2.7.01	Develop method for modeling human workload in fast-time simulations, validate models against workload measurements.	2010	D-1690, D-1710
AS.2.7.02	Develop predictive, conceptual-level, safety assessment method for ill-defined complex interacting systems (including the NAS).	2011	D-2100, R-0510
AS.3.7.01	Conduct objective analysis of service provider and aircraft operator separation assurance methods.	2010	D-1700, R-1080, R-1120
AS.3.7.02	Develop fast-time system-level simulation of NextGen technologies.	2010	D-0420, D-0880, D-0920, D-1090, D-1700, D-2100, R-0280, R-0370, R-0410, R-0510, R-0540, R-0570, R-0580, R-0590, R-0650, R-0680, R-0770, R-1120, R-1130, R-1440, R-1620, R-1630, R-2090
AS.3.7.03	Develop tools for generating future demand scenarios and analyzing NextGen data.	2010	D-1700, D-2100, R-0510, R-1080
AS.3.7.04	Develop prognostic safety assessment methods for systems and operations.	2010	D-0880, D-0920, D-1250, D-1700, D-2100, R-0510, R-0600, R-1440
AS.3.7.05	Conduct initial safety assessments of proposed concepts, algorithms, and technologies to indicate the relative safety impacts with respect to the baseline system.	2011	D-1700, R-1440
AS.4.7.01	Develop refined system-level concept of operations based on results of modeling, safety, cost-benefits, and human-in-the-loop simulations.	2011	D-1710, D-2100, R-0510, R-0570, R-0580, R-1080, R-1440

2.5 Summary

Table 2.5-I, below, summarizes the preceding tables showing the number of milestones within each RFA of the ATM-Airspace Project and the number of R&D needs and associated OIs directly supported by each RFA. As noted in the table, the number of R&D needs and OIs supported is not additive, since each RFA addresses a number of R&D needs and associated OIs that are also addressed by other RFAs.

Table 2.5-I Summary Statistics of Linkages per Research Focus Area

ATM-Airspace Project Research Focus Areas	Number of Milestones	Number of R&D Needs Supported	Number of OIs Supported
TPSU - Trajectory Prediction Synthesis and Uncertainty	16	15	20
PBS - Performance-Based Services	13	8	12
DAC - Dynamic Airspace Configuration	10	9	11
TFM - Traffic Flow Management	17	20	17
SA - Separation Assurance	29	25	24
SDO - Super-Density Operations	19	33	34
SLDAST - System-Level Design, Analysis, and Simulation Tools	14	37	36
Total	**118**	**(not additive) 54**	**(not additive) 48**

As shown, the 118 milestones of the ATM-Airspace Project support 54 R&D needs. In accordance with its responsibilities, the ATM-Airspace Project emphasizes research, and thus 48 of the supported R&D needs are research needs (R- identifiers), the remaining 16 being development needs (D- identifiers). A total of 48 OIs are directly associated with these R&D needs supported by the project.

As expected, the project activities focus largely on the Trajectory-Based and Performance-Based Operations and Support functional area of the IWP. As shown in Table 2.5-II, the ATM-Airspace Project directly supports 45 R&D needs in that functional area and 42 associated OIs, as well additional R&D needs and OIs in the Weather Information Services, Safety Management, and Environmental Management Framework functional areas.

Table 2.5-II Number of R&D Needs and OIs Supported by IWP Functional Area

NextGen Functional Areas	Number of R&D Needs Supported	Number of OIs Supported
Trajectory-Based and Performance-Based Operations and Support	45	42
Weather Information Services	2	2
Safety Management	5	2
Environmental Management Framework	2	2
Total	**54**	**48**

Table 2.5-III shows how the supported R&D needs are distributed among the RFAs. As can be expected from their broad and crosscutting nature, the ASDO and SLDAST RFAs each support a relatively large number of R&D needs. It is also worth noting, as indicated by the entries in the table, that the RFAs provide broad support for weather, safety, and environmental challenges associated with NextGen.

Table 2.5-III Distribution of Supported R&D Needs by RFA and IWP Functional Area

NextGen Functional Areas	TPSU	PBS	DAC	TFM	SA	ASDO	SLDAST	Total (row totals are not additive sums)
Trajectory-Based and Performance-Based Operations and Support	12	6	9	14	17	27	29	**45**
Weather Information Services	1			2	2	2	1	**2**
Safety Management		2		4	4	2	5	**5**
Environmental Management Framework	2				2	2	2	**2**
Total	**15**	**8**	**9**	**20**	**25**	**33**	**37**	**54**

3. CONCLUSIONS

This report presents an analysis of the alignment between the NASA ATM-Airspace Project and the R&D needs of NextGen expressed in the NextGen R&D Plan and the NextGen Integrated Work Plan (IWP). With NASA committed to focusing its research activities on NextGen, these R&D needs represent the requirements which the NASA ATM-Airspace Project must satisfy. The information in the body of this report shows how closely the project meets these requirements.

For a meaningful comparison between project activities and NextGen needs, it was necessary to perform the analysis at the level of project milestones in the NASA hierarchy and at the level of R&D needs for NextGen, since elements at higher levels are too general and too broadly encompassing.

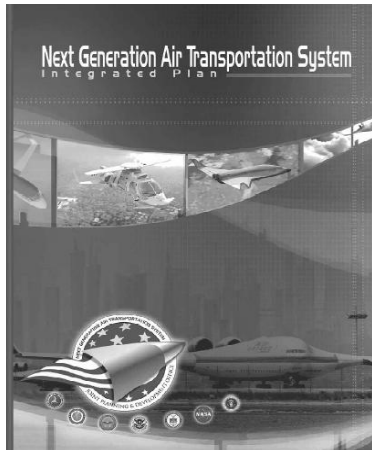
NASA program and project personnel, assisted by Crown Consulting subject matter experts, analyzed the R&D needs in the NextGen R&D Plan and linked them with the research focus areas (RFAs) of the ATM-Airspace Project. This analysis relied on practitioner knowledge, NASA program planning data, ongoing research activities, and NextGen objectives and technology needs. Additionally, the project milestones were analyzed with respect to their stated objectives, timeframes, and outcomes and were compared with the specific requirements of each of the R&D needs. As a result of this analysis, each of the project milestones within each RFA was shown to be associated with NextGen R&D needs, and each R&D need within the scope of the ATM-Airspace Project was supported by one or more milestones.

The results show that the NASA ATM-Airspace Project is very closely aligned with the documented NextGen R&D needs. Each NASA milestone will directly provide information that is required to satisfy NextGen R&D needs, and all but two milestones support two or more R&D needs, demonstrating the robustness of the activities of the project. Thus, the ATM-Airspace Project is shown to address every R&D need assigned to NASA by the IWP and within the project's responsibilities.

Analysis of the linkages established by the analysis shows that the ATM-Airspace Project supports 54 R&D needs and 48 operational improvements (OIs) identified in the IWP. Within the IWP functional area most closely related to air traffic issues, Trajectory-Based and Performance-Based Operations and Support, the project directly supports 45 R&D needs and 42 associated OIs. In addition, the seven RFAs provide broad support for R&D needs and OIs in the Weather Information Services, Safety Management, and Environmental Management Framework functional areas.

APPENDIX A – SUMMARY OF KEY NEXTGEN DOCUMENTS

A.1 National Plan



The Integrated Plan for the Next Generation Air Transportation System, also called the National Plan, was submitted to the Congress on December 12, 2004, fulfilling a requirement of P.L. 108-176, the Century of Aviation Reauthorization Act. This legislation called for an integrated plan to meet the Nation's long-term needs for air transportation safety, security, mobility, efficiency, and capacity.

The NextGen Vision

The National Plan sets forth a vision for an integrated system for 2025 capable of handling up to three times the current volume of air traffic. The air traffic management paradigm in use today dates from the 1930s; NextGen will revolutionize this paradigm with new technologies, concepts, and operational procedures. A major consideration is the leveraging of private sector capabilities as well as those of the Federal agencies involved, allowing industry to provide cost effective solutions within a performance-based set of safety, security, and environmental rules.

Improvements in air traffic management systems will result from employing advanced information management technology, enhanced sensor and detection capabilities, upgraded aircraft performance, and more accurate and tailored weather forecasts. Multilayered systems based on new technologies and up-to-the-minute information will ensure America's security. Safety will be designed into every air transportation component. Airports will increase capacity while offering convenience and security for travelers and shippers. The air transportation system will take full advantage of enhanced aircraft capabilities, but it will also accommodate aircraft with a wide variety of performance characteristics and less sophisticated equipage.

The concept of airline schedules will be redefined as the boundaries between traditional carriers and on-demand service providers begin to merge. An abundance of options will enable customers to choose air transportation services tailored to their needs. The predictability of air travel will increase, and, while delays will never be completely eliminated, NextGen travelers and shippers will have the best information to make alternative decisions in real time.

Goals and Objectives

The National Plan establishes the 6 top-level goals and 19 subsidiary objectives for NextGen shown in Table A-I, below.

Table A-I NextGen Goals and Objectives

Goals	Objectives
Goal 1 – Retain U.S. leadership in global aviation	• Retain our role as the world leader in aviation • Reduce costs for air transportation • Enable services tailored to traveler and shipper needs • Encourage performance-based, harmonized global standards for U.S. products and services to keep new and existing markets open
Goal 2 – Expand capacity	• Satisfy future growth in demand (up to 3 times current levels) and operational diversity • Reduce transit time and increase predictability (domestic curb-to-curb transit time cut by 30%) • Minimize the impact of weather and other disruptions (95% on time)
Goal 3 – Ensure safety	• Maintain aviation's record as the safest mode of transportation • Improve the level of safety of the U.S. air transportation system • Increase the safety of worldwide air transportation
Goal 4 – Protect the environment	• Reduce noise, emissions, and fuel consumption • Balance aviation's environmental impact with other societal objectives
Goal 5 – Ensure our national defense	• Provide for the common defense while minimizing civilian constraints • Coordinate a national response to threats • Ensure global access to civilian airspace
Goal 6 – Secure the Nation	• Mitigate new and varied threats • Ensure security efficiently serves demand • Tailor strategies to threats, balancing costs and privacy issues • Ensure traveler and shipper confidence in system security

NextGen Concepts

NextGen will adapt to future demands by using new concepts, technologies, networks, policies, and business models. The National Plan describes the impact of these innovations as they will affect the major elements of the air transportation system.

Flight Operations

Flight procedures will be tailored to aircraft and aircrew performance. Increased automation combined with new procedures will release ties to geographical airspace. NextGen will be integrated through the ability to share timely, accurate information with a common operational picture via secure data link, air-to-ground communication systems, and airborne Internet. All operators will be afforded access according to their differing levels of capability. Closer spacing of aircraft tailored to capabilities and conditions will enable an increase in capacity. New technologies and operational procedures will eliminate the differences between procedures for instrument meteorological conditions and visual meteorological conditions.

Security

NextGen will establish an effective security system by embedding security measures throughout the air transportation system from curb to curb, delivering security without creating undue delays, limiting access, or adding excessive costs and time. Command and control protocols will allow agencies to retain responsibility while enabling a coordinated national response to protect the homeland against all threats. Security strategies will be tailored to address a wider range of threats, considering cost and impact on operations and ensuring that security solutions are well balanced.

Safety

Air travel will remain the world's safest form of transportation. A more comprehensive safety approach will be implemented by all parties involved in aviation. This approach changes the regulatory authority's role from testing, inspecting, and certifying individual system elements to comprehensive approval and periodic audits of safety management programs within the civil aviation industry. Responsibility for safety risk management and design assurance will reside with the aviation industry, within appropriate rules and oversight.

Airports

The airport infrastructure to meet future demand will be developed by empowering local communities and regions to create alternative concepts for use and management of airports. Arrival and departure capacity at busy airports will increase through greater use of parallel runways, relaxation of single-runway occupancy restrictions, and improved wake vortex sensing and prediction systems integrated with automated approach, landing, and departure systems. Multiple airports in a geographic region will maintain positive community relationships and coordinate planning to provide a range of facilities that balance transportation needs with environmental standards for noise and emissions. Airports and air traffic services will use market-based mechanisms such as peak period pricing to ease congestion and ensure that maximum economic value is obtained from available resources.

Aircraft Operations

Future aircraft will sense, control, communicate, and navigate with increasing levels of autonomy, enabling new concepts in air traffic management. Flight deck automation will reduce the potential for aircraft to maneuver into unsafe situations, preventing controlled flight into terrain, aircraft collisions, and airspace violations. Global procedures for operating and spacing aircraft based on the capability of an individual aircraft and the flight crew's operational performance will promote common operations worldwide.

Air Traffic Management

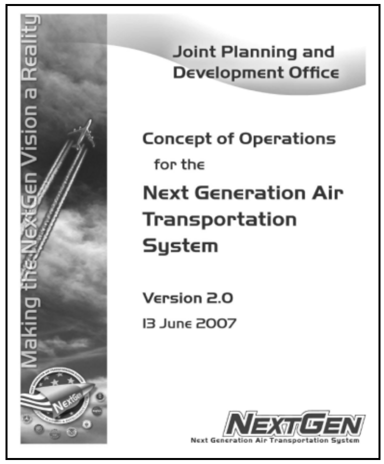
NextGen will change the air traffic management paradigm, enabling the provision of services to airspace users on-demand from any geographical location. In addition, the air traffic management system will be enhanced by several key features, including:

- Reduced separation standards
- Flexible spacing and sequencing of aircraft on the ground and in the air
- New equipment, procedures, and infrastructure, enabling increased use of underutilized airspace, airports, and runways

- Reduced impact of weather through a systemwide capability for enhanced weather observations and forecasts integrated with the tools used by air operators.

To accommodate shifts in demand from a wide variety of users, air traffic control will migrate from control of individual flights to air traffic management whereby airspace is allocated based on traffic flows. The role of dispatchers, flight planners, controllers, and flow managers will emphasize end-to-end strategic flow management with minimal individual flight interventions. Decisionmakers will use information management systems to collaborate, develop, and update flow plans and to react and recover from system disruptions.

A.2 NextGen Concept of Operations



The Concept of Operations (ConOps) for the Next Generation Air Transportation System, Version 2.0, was released by the Joint Planning and Development Office (JPDO) on June 13, 2007. This document provides an operational point of view of how the goals and objectives of NextGen will be met by the system envisioned for 2025. In many cases this document presents “aggressive” concepts that have not yet been validated, but are envisioned to maximize benefits and flexibility for NextGen users.

NextGen Operational Needs

NextGen operational needs stem not only from the expectation to accommodate up to three times today’s traffic levels, but also from the need to accommodate a wide variety of users with broad aircraft performance envelopes and diverse operational needs within the same airspace.

Future users are expected to represent varying levels of total system performance via onboard capabilities and associated crew training. Many aircraft will be able to perform airborne self-separation, spacing, and merging tasks and precisely navigate and execute four-dimensional trajectories (4DTs). Aircraft will also have varying levels of ability for transmission and receipt of cooperative surveillance information and weather information, as well as a wide range of capabilities for cruise speed, cruise altitudes, turn rates, climb and descent rates, stall speeds, noise, and emissions. Aircraft operators will have a diverse range of capabilities and operating modes and will consequently pose varied operational demands.

Another major aspect of NextGen is providing environmental protection that allows sustained growth of aviation. Community noise and impacts on local air quality must be reduced compared to today, despite the increased traffic volume.

Key Characteristics

NextGen combines advanced technologies and operational capabilities, innovative ATM concepts, environmental improvements in airframe and engine technology, appropriate policy approaches, and financial support to meet these needs. Its key characteristics, as described in the ConOps, are summarized in the section which follows.

User Focus. A major theme of NextGen is an emphasis on more flexibility and information to users while reducing the need for government intervention and control of resources. NextGen provides greater situational awareness and data accessibility, and it aligns government structures, processes, strategies, and business practices with customer needs. Multiple service levels permit a wide range of tailored services to satisfy individual user needs and investment choices. Capacity is expanded to meet demand by investing in new infrastructure, shifting NextGen resources (e.g., airspace structures and other assets) to meet demand, implementing more efficient procedures (e.g., safely reducing separation between aircraft to increase throughput), and minimizing the effects of constraints such as weather.

Distributed Decisionmaking. As far as possible, decisions in NextGen are made at the local level, with an awareness of systemwide implications and guided by NAS-wide objectives. Local decisionmaking includes an increased level of participation by the flight crew and Flight Operations Centers (FOCs). Stakeholder decisions are supported through access to a rich information exchange environment and transformed collaborative decisionmaking that allow wide access to information by all parties while satisfying privacy and security constraints. With more timely access to information, increased situational awareness, and consistency of information for all decisionmakers, decisions can be made more quickly, required lead times for implementation can be reduced, responses can be more specific, and solutions can be more flexible to change.

Integrated Safety Management System. NextGen applies an integrated Safety Management System **(**SMS) approach to identify and manage potential problems. This approach to managing safety risk includes systematic procedures, practices, and policies for safety management. Safety policy defines how the organization will manage safety as an integral part of its operations. Safety risk management is applied to identify and assess hazards and control the risk. Safety assurance ensures that organizational products or services meet or exceed safety requirements. Safety promotion is used to promulgate safety information and strengthen the safety culture.

International Harmonization. The ATM system is globally harmonized through collaborative development and implementation of identified best practices. International harmonization includes advocating for the highest operational standards for aircraft operators and air navigation service providers to ensure the safety of the global air transportation system. ICAO Planning and Implementation Regional Groups or multilateral agreements harmonize planning and implementation of NextGen transformations.

Taking Advantage of Human and Automation Capabilities. NextGen capitalizes on the combination of human and automation capabilities to enhance airspace capacity, aviation safety, and operational efficiency. Humans do what they do best - choose alternatives and make decisions - and help automation functions accomplish what they do best: acquire, compile, monitor, evaluate, and exchange information. Research and analysis will determine the appropriate functional allocation of tasks among air navigation service providers, flight operators, and automation and determine when decision support tools are necessary to support humans and which functions should be completely automated without human intervention.

Weather Operations. In the NextGen environment, weather information is integrated with and supports NextGen automation and human decisionmaking processes. A common weather picture used by all stakeholders facilitates improved communications and information sharing. Weather data is translated into information directly relevant to NextGen users and service providers. Flight trajectory plans are developed with an increased understanding of the potential severity and probability of weather hazards. As a result, less airspace is constrained because of weather.

Decision support systems directly incorporate weather data. Probabilistic forecasts to address weather uncertainty and improved forecast accuracy further minimize the effects of weather on NextGen operations.

Environmental Management Framework. Environmental management enables capacity increases consistent with environmental goals. An integrated suite of new technologies, procedures, and policies minimizes community noise and adverse impacts on local air quality and mitigates water quality impacts, energy use, and climate effects. NextGen environmental compatibility is achieved through a combination of improvements in aircraft design, aircraft performance and operational procedures, land use around airports, and policies and incentives to accelerate technology introduction into the fleet. Intelligent flight planning and improved flight management enable optimal route selection and approach and landing procedures.

Robustness and Resiliency. NextGen is more resilient in responding to failures and disruptions, including contingency measures to provide maximum continuity of service in the face of major outages, natural disasters, security threats, or other unusual circumstances. Increased reliance on automation is coupled with fail-safe modes that do not require full reliance on human cognition as a backup for automation failures. NextGen maintains a balance of reliability, redundancy, and procedural backups, providing a system that not only has high availability, but also requires minimal time to restore failed functionality.

Scalability. NextGen is adaptable to meet the changes in traffic load and demand that occur day to day or over the decades to come. Increased use of automation, reduced separation standards, super-density arrival and departure operations, and use of additional runways allow busy airports to move a large number of aircraft through the terminal airspace during peak traffic periods. New capabilities, such as virtual towers, enable the cost-effective expansion of services to a significantly larger number of airports than is possible with current methods of service delivery.

ATM Transformations

As stated in the preface to the ConOps document, the development of the ConOps is an iterative and evolutionary process. Consequently, the current version focuses on capabilities and concepts, rather than detailed procedures. The specificity of the ConOps is expected to increase in step with the development of the Integrated Work Plan and the incorporation of stakeholder feedback, lessons learned, evolution of user and public needs, and development of new technologies.

A major focus of the ConOps is and will continue to be the transformation of air traffic management. Table A-II, below, summarizes the major transformative capabilities described in the ConOps.

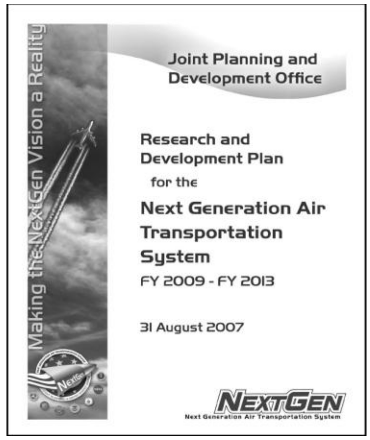
Table A-II Comparison of NextGen and Current ATM Capabilities

2006 Current Capability	2025 NextGen Capability
Roles and Responsibilities	
• Primary roles for ATC services are air traffic controllers and ATM specialists. • Demand/capacity imbalances are managed through broad flow contingency initiatives.	• New ANSP roles focus on CM, FCM, and TM. • DSTs enable more strategic decision-making. • Air traffic controllers continue to serve classic airspace.
Collaborative Air Traffic Management	
• Focus is on managing demand to meet available capacity. • ATM initiatives are conservative and broad. • Communications are usually verbal and written. • Conservative measures are used to manage uncertainty caused by weather and other capacity constraints.	• Focus is on allocating NAS assets to maximize capacity to meet user demand. • There is better decision support and integrated strategic and traffic flow management (TFM). • There is better use capacity in presence of uncertainty. • A broader set of flight operators participates in C-ATM process.
Integration Across Strategic and Tactical Decision Horizons	
• Stakeholders have limited ability to exchange data supporting integrated decision-making. • Uncertainties in demand, weather, and flight trajectories are cognitively handled by ANSP personnel using operational judgment.	• SSA and integrated impact assessment tools provide stakeholders with common awareness of situations and impacts of decisions. • Automation incorporates probabilistic data to reduce likelihood of overly conservative decisions.
Trajectory-Based Operations	
• Flights are managed via verbal delivery of clearances and vectors. • Time-based metering is used in some localities to improve predictability and throughput. • Required navigation performance (RNP) operations are used initially to manage complexity and increase capacity.	• Flights are managed through use of 4DTs that specify accurate current and future aircraft position. • Metering, controlled time of arrival (CTA) exchange, and more flight-specific adjustments increase overall throughput and operator efficiency. • Safety, security, and environmental considerations are integrated in TBO. • Flight crew–initiated, dynamic trajectory adjustment is possible with ATM and airport operations center (AOC) collaboration.
Dynamic Resource and Airspace Management	
• Airspace classification is largely fixed, with Earth-referenced boundaries. Sectors may be combined during low demand. Class B and C airspace volumes are defined to protect all possible runway configurations and to match charting capabilities. • Delivery of services is constrained by geographic location of physical facilities.	• Airspace allocation is flexible over different time horizons and geographic boundaries to meet demand. Airspace restrictions for aircraft capability are applied only when needed (e.g., for capacity, safety). • Changes to airspace configuration are provided dynamically to flight crews so that maximum flexibility is possible. • Delivery of services is flexible and not constrained by geographic location of personnel and infrastructure.

Table A-II (Continued) Comparison of NextGen and Current ATM Capabilities

2006 Current Capability	2025 NextGen Capability
Reduced Impact of Weather	
• Ability to deal with weather is often limited to Severe Weather Avoidance Program and similar initiatives. In-flight rerouting causes significant delays and flight inefficiencies. • Visibility limits surface, arrival, and departure operations.	• Weather information is integrated into automation, improving decision-making. • Forecast and current weather measurements are improved. • Operations are supported independent of visibility and make better use of forecast uncertainties.
Separation Management	
• Tactical separation by individual controller visualizing aircraft trajectories on radar screen and issuing voice instructions limits throughput and flight efficiency. • DSTs provide controllers with strategic awareness of future conflicts and provide capability to evaluate alternative solutions. • Separation standards are relatively fixed.	• Separation provision, both airborne or by ANSP, relies heavily on automation support, allowing reduced and performance-based separation standards for different airspace categories. • 4DTs of many aircraft following similar routes may be aligned to nearly eliminate conflicts. • Trajectory changes required for separation assurance are communicated digitally.

A.3 NextGen R&D Plan



The Research and Development Plan (R&D Plan) for the Next Generation Air Transportation System FY 2009–FY 2013 was submitted to the Office of Management and Budget (OMB) on August 31, 2007, in response to a request for “a research and development plan that details the requirements for needed technologies and identifies the responsibilities of each JPDO member agency.” The plan focuses on investments between FY 2009 and FY 2013 considered in FY 2009 budget deliberations, but it includes activities extending beyond FY 2013 that must take place during this period. Most vitally, this plan specifies R&D needs for timely introduction of NextGen operational improvements; these establish the link between NASA research and NextGen.

R&D Plan Overview

Consistent with its purpose, the R&D Plan addresses research issues associated with the ConOps and identifies specific R&D needs. The R&D Plan is organized in terms of 12 R&D areas that were obtained by considering the Solution Sets established in the FAA Operational Evolution Partnership (OEP). For each R&D area, key NextGen challenges are captured as a set of problem areas. Within each problem area, the R&D Plan presents a hierarchy of outcomes, objectives, and R&D needs. The outcomes are defined as the desired changes in operations, independent of the solutions being pursued. R&D objectives capture major solutions necessary to achieve the desired outcomes.

The R&D needs represent knowledge required to achieve the outcomes and objectives. Each R&D need consists of a statement of what the need is, when it is needed, and what agencies will participate in its accomplishment. These R&D needs are the final product of the flowdown and provide the information to which the NASA research may be compared to ascertain its relevance.

NextGen Epochs

To make the transformation to NextGen more understandable and manageable, the R&D Plan introduces the concept of phases, or Epochs, corresponding to major steps in the maturation of research to implementation. Epoch 1 (FY 2007–2011), focuses on developing and implementing mature foundational technologies, including Automatic Dependent Surveillance-Broadcast (ADS-B), Required Navigation Performance (RNP), System-Wide Information Management (SWIM), Data Communications (DataComm), and NextGen Network-Enabled Weather (NNEW). It is also a critical period for research and development, in which long-term capabilities are better defined and development activities reduce risk and inform decisions concerning mid-term deployments.

Epoch 2 (FY 2012–2018) builds on this foundation to enable aviation to grow in response to market conditions and passenger demands rather than reacting to constraints of air traffic management. The introduction of automation and new procedures allows pilots to play a more active role in the system through delegated spacing, merging, and passing. The expansion of precision navigation, implementation of advanced weather capabilities and advanced data communications, and development of the critical infrastructure for operations in high-density areas will result in greater operational flexibility and efficiency. NextGen trajectories will be exchanged via datalink, enabling trajectory-based operations and enhancing the integration of flow management with air traffic control. Collaboration and decisionmaking will be seamless across domains, allowing efficient airborne flow programs that reduce the impacts of weather.

Epoch 3 (FY 2019–2025) expands NextGen capabilities into a nationwide system, resulting in a cohesive architecture that allows aviation services to be adapted and tailored to accommodate varying operational needs and demand profiles. It solidifies, expands, and fine-tunes the changes made in Epoch 2 and completes the extension of NextGen to secondary airports. It also allows more complex high-density operations across the system to take full advantage of the available airspace and the precision provided by satellite-based technologies.

Summary of R&D Needs

The R&D Plan presents the R&D needs organized according to the R&D areas derived from the OEP Solution Sets. These needs are summarized below for each of the 12 R&D areas. Although not all the R&D areas represent a focus for the ATM-Airspace Project, certain project activities may play a supporting role.

Trajectory-based Operations

Trajectory-based operations (TBO) represent a shift from clearance-based to trajectory-based control. Aircraft will fly negotiated trajectories, and ATC will transition to management-by-trajectory. The traditional roles of pilots and controllers will evolve as automation and new procedures support the transition. Managing traffic by trajectory will increase capacity and allow more operators to fly preferred, fuel-efficient routes within constraints such as weather.

Major research focuses on integrating the dual use of 4DT for clearances and dynamic airspace planning, coupled with alternative roles in maintaining separation assurance for avionics, aircraft operators, ground automation, and service providers. Research to integrate the planning and clearance aspects of 4DT must also focus on when to use airspace structure and when to use self-separation. Substantial research on delegating merging, spacing, and separation tasks and the allocation of control responsibilities among pilots, controllers, and automated systems is essential to developing performance-based separation procedures.

Reduced Impact of Weather

Today, weather data are not well integrated into automated decision support systems, are not readily available to all decisionmakers, and are not sufficiently accurate. NextGen decision support systems will integrate weather information, along with probabilistic forecasts, to better manage weather impacts and enable proactive planning. The most significant research will determine the accuracy and other characteristics of an authoritative weather information source for decisionmaking. The structure will be put in place to manage the development, authorization, standards, policy, and certification of the virtual NextGen Network-Enabled Weather system to leverage the development of net-enabled weather observations and probabilistic weather forecasts and to provide a common authoritative source of current and forecasted weather information.

Flexible Terminal Airspace and Expanded Airport Access

To meet the growth in traffic demand, NextGen will rely on the expanded use of secondary and reliever airports and fuller use of all airports in most weather conditions. Capabilities that will accommodate higher traffic levels include more reliable access in low-visibility conditions and more flexible use of terminal airspace to meet traffic demand. Improved pilot and controller situational awareness will allow flexibility in air traffic service delivery. Flexibility in using terminal airspace will stem from changes in provisions for air traffic services at a local level to take advantage of improved situational awareness and trajectory-based operations. These services will include Area Navigation (RNAV)/RNP routings, continuous descent approaches, dynamic terminal airspace, and other performance-based procedures.

Research will address performance gains that can result from flexible airspace structures and the means for dynamically adjusting airspace allocations. Other research will focus on use of continuous descent arrivals in high-density terminal airspace and on addressing aircraft wake turbulence in establishing new trajectory-based or display-enhanced procedures. Initial efforts will identify the requirements to incorporate this functionality into ground management of the trajectory, with subsequent research addressing options to move it to the cockpit display.

High Density Terminal and Airport Operations

Peak throughput is critical in high-density airspace. High-density airports are characterized by a high demand for runway access and multiple runways with airspace and taxiing interactions, and their proximity to other airports can result in airspace or approach interference. These airports will require integrated tactical and strategic flow capabilities in addition to all the capabilities of flexible terminals and airspace. They might also require higher performance navigation and communications. New procedures will be needed to improve airport surface movements, reduce spacing and separation requirements, and improve traffic flows.

Research will establish cases or conditions that warrant performance-based separation standards, including what must be done to increase throughput on the surface and individual runways, manage closely spaced parallel operations or multiple runway operations, and coordinate separation in the transition airspace of a metropolitan area. Research into the use of onboard displays in combination with 4DT-based separation will feed into development of the necessary avionics and ground infrastructure.

Collaborative Air Traffic Management

Today’s air traffic control system uses relatively coarse tools to manage imbalances between demand and capacity. The objective of collaborative air traffic management is to accommodate operators’ preferences to the extent possible and impose restrictions only when necessary. This concept strives to adjust airspace and other resources to support demand, rather than constraining demand to match available assets. If constraints are required, the goal is to maximize operators’ opportunities to resolve them.

Research focuses on refining the understanding of uncertainty in forecasting weather and demand, their impacts on capacity and safety, and options for automating detection and resolution. This research will build on discoveries from earlier steps and is essential for tailoring weather services to best serve their intended uses. Research in trajectory and flow management will focus on developing an integrated, collaborative ATM capability that provides usable information based on forecast traffic, system configuration, and weather, and on probabilistic tools that allow decisionmakers to analyze alternatives for addressing operational disruptions.

Safety

NextGen requires a fundamental change in safety management. To maintain or improve on today's low accident rates with the much higher traffic volumes and densities projected for NextGen will require an even greater level of safety than is present in the current system. Today's reactive data analysis must evolve into prognostic evaluations to address safety risks in a higher capacity, increasingly complex operating environment. This will require a formal, systematic, business-like approach to managing safety risk, embodied in the form of Safety Management Systems (SMSs). Safety research will focus on procedures, technologies, and automated recovery capabilities to address the most significant safety hazards, including loss of control, weather encounters, and mechanical failures. This research leads to applications in aircraft and avionics at the beginning of the third epoch.

Layered, Adaptive Security

Layered, adaptive security is a risk-informed system that depends on multiple technologies, policies, or procedures, scaled and arranged to deter, prevent, detect, defeat, or mitigate a given threat. The National Strategy for Aviation Security states that "a layered approach to aviation security means further applying some measures of security to each of the following points: transportation; staff; passengers; conveyances; access control; cargo and baggage; airports; and in-flight security [to] allow for resilience against expected and unexpected attack scenarios."

Environment

Changes in technology, aircraft operations, procedures, and environmental practices are necessary to mitigate the significant environmental effects that will result from increased air transportation. The primary environmental concerns arise from impacts on community noise, local air quality, global climate, water quality, and energy production and consumption. The NextGen environmental management framework considers the interdependencies among the many environmental issues, so that in addressing some, others are not exacerbated. The NextGen environmental challenge is to manage the environmental effects of aviation in a manner that reduces or limits their impacts while allowing sustained aviation growth. Research on tools for analysis of noise and emissions will allow 4D trajectories and traffic flows to be considered in airport planning. Research is also needed to provide a better understanding of the health and welfare effects of noise, local air quality, and global emissions and to translate these into environmental standards.

Transformed Facilities

NextGen leads to a more seamless view of air traffic, organized not by geographic sectors, but by aircraft trajectories. Automation and other supporting infrastructure will be designed to support this operational concept. Facilities and the personnel who staff them must also evolve from a geographical focus to a broader concept for air traffic management. The most significant research concerns efficiency and productivity improvements for delivering air traffic services, including facility-independent techniques and practices and methods for dynamically allocating demand to air traffic management personnel; this research will drive the roles of facilities and personnel for NextGen operations. Another key research priority is to understand the extent of the need for dynamic allocation of airspace and resources.

Aircraft, Operator, and Air Transportation User

This area focuses on changes in the aircraft or operator support environment through fundamental capabilities beyond individual enhancements to safety, security, environment, or air traffic management. The transition to NextGen will require a suite of improvements to airframes and avionics, and the capability to reduce the time required to make changes. Airframe changes include vehicle enhancements that support NextGen operations and the management and operation of remotely piloted or uncrewed aerial systems (UASs). Research will focus on control systems and sense-and-avoid capabilities for UASs, and avionics development will benefit and borrow from developments of 4DT operations in low visibility and the virtual-tower concept.

Airport and Air Transportation Infrastructure

Airports are the nexus of many transformational elements of NextGen, but the structure of this element is very complex. While the Airport Improvement Program funds some airport improvements, airport development is generally controlled and funded locally. Airport safety and design standards are federally regulated, but airports are owned, managed, and operated at the local level. To handle the increased demand of aircraft, passengers, and cargo, airport operators must integrate requirements for security, the environment, and air traffic operations.

Crosscutting Research and Development

Although human factors is an essential part of many concepts described in the R&D Plan, it is addressed in this section to highlight its importance and wide applicability. Crosscutting research will also be needed to model NextGen mission needs and to continually assess performance implications of a changing operational environment.

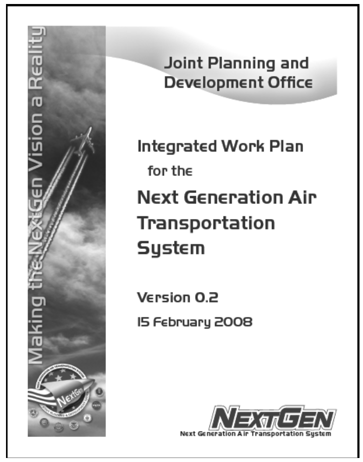
Sample Description of R&D Needs

Each R&D need is described in terms of the need, the date by which it is needed, the lead and participating agencies in its development, and which operational improvements it supports. Each R&D need is also given a number for data handling and traceability; research needs are identified with the prefix R, development needs are identified with the prefix D. Figure A-1, below, shows a sample of this information for a research need (R-0380) related to TPSU, ASDO, and SLDAST.

ID	Description of Need	Required Completion Date	Lead Agency	Supporting Agencies	Supported First Tier OIs
R-0380	Complete applied research on aircraft-derived position and intent information to support the definition of initial data exchange requirements for advanced application in high density terminal areas	2011	NASA	FAA	OI-0326: Airborne Merging and Spacing - Single Runway

Figure A-1 Sample Description of a Research Need from the NextGen R&D Plan

A.4 NextGen Integrated Work Plan



Version 0.2 of the NextGen Integrated Work Plan (IWP) was issued by the JPDO on February 15, 2008. The IWP lays out a long-term transition to the 2025 vision for NextGen embodied in the ConOps. This issue is a revision of version 0.1 of the plan, issued in July 2007; future versions will result from vetting with JPDO partners and stakeholders. The IWP is essential to the development of NextGen because it describes all the work necessary to realize each of the operational improvements, including research activities. For that reason, it is particularly important to NASA's goal of aligning the Airspace Systems Program with NextGen R&D needs.

IWP Overview

The Integrated Work Plan describes NextGen research, policy and implementation activities, including schedules, and their dependencies. As such, it provides a collaborative planning and management tool for all of the mission partners. The research activities are derived from the R&D needs identified in the R&D Plan dated February 15, 2008. The scope of the IWP is broader, however, since it contains the full spectrum of work required by NextGen. In addition to its added scope, the IWP shows the dependencies among R&D and other implementation activities. The IWP is the governing JPDO document, and thus supersedes the R&D Plan. As with the R&D Plan, the IWP provides the fundamental information to which the ATM-Airspace Project must respond if its research is to be aligned with NextGen.

The IWP is organized around the major functional areas of the NextGen enterprise, which were derived from the ConOps and enterprise architecture. These functional areas are:

- Trajectory-Based and Performance-Based Operations and Support
- Airport Operations and Support
- Weather Information Services
- Safety Management
- Layered Adaptive Security
- Environmental Management Framework
- Net-Centric Infrastructure Services
- Positioning, Navigation, and Timing Services
- Surveillance Services

Each functional area is described in terms of operational improvements and the enablers, R&D activities, capital improvements, policies, and decisions that are needed to realize each operational improvement. The R&D activities in the IWP correspond to the R&D needs expressed in the R&D Plan, the change in designation from need to activity reflecting the intent of the IWP as a plan for actions rather than a set of requirements.

Operational Improvements and Associated Activities

Operational improvements (OIs) provide the core framework for NextGen. OIs describe an improved level of performance or specific capability of NextGen operations. They are realized through the combination of one or more enablers as well as one or more R&D activities, investments, policy elements, or decisions. They can also be supported by the achievement of one or more prerequisite OIs. Enablers describe the fundamental functional elements of the NextGen enterprise, such as communication, navigation, and surveillance systems. OIs and enablers have an initial operating capability (IOC) date or availability date, respectively, and other activities have a specified completion date. As shown in Figure A-2, below, operational improvements can support other operational improvements, and, likewise, enablers can support other enablers. Any of the activities can support a number of enablers or operational improvements.

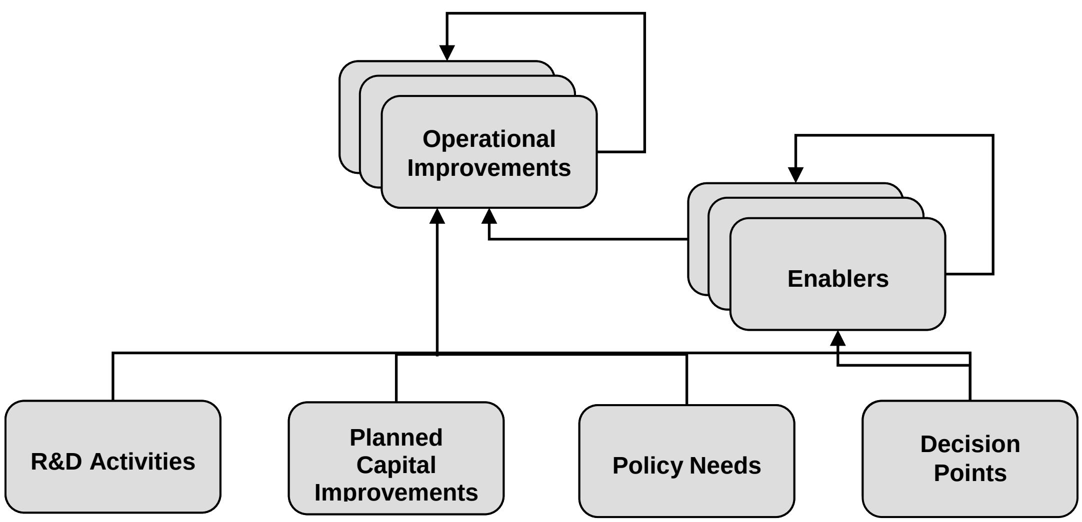


Figure A-2 Integrated Work Plan Data Elements

Because of the complexity of NextGen, each OI usually requires several enablers, R&D activities, policy decisions, and investments. Figure A-3, below, illustrates the various elements that support an OI by describing the enablers, key decisions, policy issues, and R&D activities that are required to implement a representative OI: in this case, OI-0355, En Route Airborne Merging and Spacing. In addition to the activities shown in the table, this OI is supported by seven investments, as described in the IWP.

Functional Area: Trajectory Management - En Route/Multi-Domain		
Operational Improvement: OI-0355 En Route Airborne Merging and Spacing: Flow of traffic through constrained En Route airspace, such as weather-constrained airspace, is expedited through the use of airborne merging and spacing to increase capacity while reducing ANSP workload. This OI includes development of ANSP capabilities and procedures and provides greater traffic throughput, reduced ANSP workload/ transactions, and greater trajectory maneuver efficiencies than via ANSP clearances. Design decisions are required before implementation to determine the most cost/beneficial and effective method for expediting flow of traffic through constrained En Route airspace and to develop how this would be implemented in TBO airspace. **IOC: 2015.**		
Prerequisite Enablers		
ID	**Available**	**Name**
EN-1023	2010	Cooperative Surveillance - ADS-B Out Level 1
EN-1400	2010	Cooperative Surveillance - ADS-B IN/TIS-B/FIS-B Level 1
EN-0016	2012	Separation/Trajectory Management Detail Operational Concept
EN-0015	2013	Air - Ground Data Exchange - Strategic Trajectory Requests
EN-0031	2013	Avionics - Airborne Merging and Spacing
EN-0035	2013	Separation Management Decision Support - Level 1
EN-2010	2013	Network-enabled Weather Information - Level 1 Initial 4D Wx Cube
EN-2680	2013	Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 1 Initial
EN-0012	2014	Air - Ground Data Exchange - Traffic Management Level 1: Controller-Pilot Data Link
EN-0013	2014	Air-Ground Data Exchange - Trajectory Management Level 1: Route Clearances
R&D Actions		
ID	**Completed**	**Name**
R-0530	2012	Complete applied research on ground and aircraft automated separation management options to guide the selection of technology and procedures development for TBOs in performance-based airspace. Primary Responsibility: NASA, Supporting OPRs: FAA, Industry
Key Decisions		
ID	**Required**	**Name**
KD-0001	2008	Decide to fully fund and implement the ADS-B program to include publishing the ADS-B Notice of Proposed Rulemaking
KD-0098	2011	Operational approval for delegation of Merging and Spacing (and/or similar operations) to aircraft (with overall separation assurance responsibility retained by ANSP)
Policy Issues		
ID	**Required**	**Name**
PI-0014	2008	Aircraft Equipage Implementation Policy
PI-0016	2008	Streamlined avionics certification processes
PI-0064	2008	Airline Equipage Requirements - Global Harmonization
PI-0120	2008	Positioning, Navigation, & Timing Performance Requirements
PI-0012	2011	Standards Surveillance International Data Exchange
PI-0067	2011	Avionics - Global Harmonization

Figure A-3 Example of an OI (OI-0355) and Prerequisite Activities

To illustrate the scope of the IWP, Table A-III, below, provides a breakout of the number of elements associated with each functional area.

Table A-III Number of IWP Activities in Each Functional Area

Functional Area	Operational Improvements	Enablers	R&D Activities	Policy Needs	Decision Points
Trajectory-Based and Performance-Based Operations and Support	67	87	83	13	12
Airport Operations and Support	14	35	6	12	4
Weather Information Services	4	58	8	3	5
Safety Management	22	61	13	10	4
Layered Adaptive Security	24	41	22	14	10
Environmental Management Framework	9	39	22	5	4
Net-Centric Infrastructure Services	--	33	5	5	10
Positioning, Navigation, and Timing Services	--	15	6	4	4
Surveillance Services	--	32	2	5	4
Total	**140**	**401**	**167**	**71**	**58**

R&D Activities

The R&D activities in each functional area are aligned with OIs and enablers to describe the dependencies and sequencing necessary to achieve NextGen in a timely and efficient manner. The R&D activities of interest to the ATM-Airspace Project are covered in the IWP sections for the functional areas Trajectory-Based and Performance-Based Operations and Support, Weather Information Services, Safety Management, and Environmental Management Framework. Since the R&D activities for the IWP are drawn from the R&D needs specified in the R&D Plan for FY 2009–2013, they emphasize near-term needs, but they do include all R&D that is necessary within that time frame, including R&D activities that extend to completion beyond FY 2013. The discussion which follows summarizes the thrust of the R&D activities relevant to ATM-Airspace Project research; the IWP includes more specific descriptions of each of the 167 R&D activities.

The following paragraphs summarize the research and development topics described in the IWP for each of the major functional areas of NextGen:

- Trajectory-Based and Performance-Based Operations and Support
- Airport Operations and Support
- Weather Information Services
- Safety Management
- Layered Adaptive Security
- Environmental Management Framework
- Net-Centric Infrastructure Services
- Positioning, Navigation, and Timing Services
- Surveillance Services

Trajectory-Based and Performance-Based Operations and Support

The Trajectory-Based and Performance-Based Operations and Support functional area is subdivided into Air Navigation Operations, Air Navigation Support, and Flight Operations and Support.

Air Navigation Operations

The primary research for Air Navigation Operations will define the best way to implement 4D trajectory (4DT) operations. By 2012 the first round of research in this area will integrate 4DT planning with the separation assurance function in terminal airspace. Development of standards for integrated navigation, communications, and flight controls to fly precise trajectories will follow by 2015.

The 4DT functionality is strongly affected by the separation assurance roles of aircraft operator, ground automation, and service provider. Responsibility assignments for separation will depend on specific separation situations and the need for reductions in spacing to safely increase capacity. By 2012, research will determine the merits of the various ground, aircraft, and automation separation management options. The selected separation procedures will influence the requirements for negotiating flexible flight-specific trajectories and the use of dynamic airspace structures such as high-density corridors or self-separation airspace. By 2014, research will establish specific procedures for use of 4DT and the interactions between flight trajectory negotiations for individual flights and the use of dynamic airspace structures.

With the new allocation of control responsibilities, it will be possible to identify opportunities to gain capacity, safety, or flexibility by establishing performance-based procedures. By 2015, research on control systems, sense-and-avoid capabilities, collision avoidance, and emergency procedures will establish the requirements to incorporate beneficial performance-based procedures into trajectory-based airspace.

The most significant challenge will be the system for maintaining the 4DT proposals and agreements across a broad span of time. This system must also account for a probabilistic distribution of capacity resulting from weather and other contingencies. The research in these areas will conclude by 2015 with the establishment of requirements for collaborative automated flight and flow evaluation and resolution.

Air Navigation Support

The use and extent of dynamic allocation among air navigation services provider (ANSP) facilities enabled by the creation of dynamic airspace structures is the most significant research area for defining the support environment. Flexible allocation of air traffic management resources will drive the networking of systems for information sharing and backup. By 2012, research will determine the methods for dynamic allocation of air traffic management resources and designation of airspace structures such as self-separation areas. By 2013, research will identify facility needs for flexibility in airspace design and techniques for exploiting performance- based trajectories with shifts in ANSP team sizes and skill sets.

At the same time, research into how capacity is affected by workload allocation and facility configuration will result in tools for matching capacity to demand. These tools will address projected weather impacts, among others. By 2014, research on automated capacity problem detection, notification, coordination, and resolution will result in procedures to account for real-time assessments of the accuracy and reliability of probabilistic weather forecasts.

Other significant tradeoffs to be considered include the allocation of airspace among classes of users, among airports in a metro area, and between military and civil purposes when there is a capacity gap. Research on airspace structures and collaborative planning will contribute to defining 4DT allocation schemes for collaborative planning by 2015. This decision in turn will drive the research to define what specific airspace structures (such as flow corridors, self-separation, and special use airspace) are needed to support trajectory-based operations. This research will allow development of ATM-wide procedures and common automation, as well as specific solutions such as virtual towers, by 2015.

With potentially significant negotiations and separation management functions involving the cockpit, modular or incrementally upgradeable avionics and accelerated certification will be needed for timely transition. By 2012, research will establish the basis for development and certification of elements of system-of-systems in a piecewise fashion to enable routine upgrades. Such a capability will be useful in implementing the avionics suites to enable performance-based separation procedures. Research into the role assigned to the aircraft in separation assurance in conjunction with or in lieu of trajectory-based operations will define the avionics requirements. By 2015, research will address cockpit technologies and procedures for very closely spaced parallel, triple, and quadruple runways.

In 2018, development of a second round of tools and network facility capabilities will allow capacity to be expanded and complexity to be managed in high-density environments through means such as performance-based separation standards and 4DT for separation assurance.

Flight Operations and Support

Flight operations and support research will focus on weather detection, mitigation, and avoidance and on reducing separation of aircraft to account for the effects of wake vortex. Research will also support selection and prioritization of alternative aircraft capabilities, development of policy for standards development and certification, and formulation of policies regarding incentives or access-based mandates for airborne capabilities through 2020. These research efforts will consider the operational diversity of commercial, military, business aviation, and general aviation operations. An additional topic is applied research on staffed and automated virtual tower options and other mechanisms to expand service to more airports.

Airport Operations and Support

The most significant challenges for airport operation will be to find methods for increasing throughput of passengers, baggage, and cargo through the terminals, including security and Customs and Border Protection. The most significant research will focus on what information and tools are necessary for more robust calculations of the interdependencies among system components, including environmental effects and the integration of airport data such as surface conditions and deicing operations into real-time management of airside and landside resources This research will support mid-term implementation of airport operations tools to support the expected throughput based on all relevant parameters. Another research area is the investigation of pavement options that would reduce down time due to ice or snow removal.

Weather Information Services

Weather Information Services required for trajectory-based and performance-based operations include a common weather information source for decisionmaking, adaptable observation information, and weather forecast products tailored to their procedural applications. In 2013 the structure will be in place to manage the development, authorization, standards, policy, and certification of the virtual NextGen Network-Enabled Weather (NNEW) to provide a common, single authoritative source of current and forecasted weather information. It will leverage net-enabled weather observations and probabilistic weather forecasts developed by 2012. By 2016 a second round of network-enabled observations and predictive model improvements will be developed to support more advanced flexible airspace and trajectory-based operations. It will use adaptive controls to direct observation sensors on aircraft and satellites in real time. This round will also enable aircraft to participate more fully in the observation network and receive information tailored to performance-based procedures, such as turbulence, wake, or icing data.

Safety Management

The NextGen goals are to be achieved through a combination of new policies, procedures, operations, and advances in technology deployed to safely manage passenger, air cargo, general aviation, and air traffic operations. Safety improvements include changes to aircraft and ground systems, manufacturing methods, vehicle and ground systems health management and maintenance, systems to counteract the effects of the environment on operations and, most importantly, human-centered interfaces for air and ground systems. Research is targeted to deliver recommended tools and safeguard solutions for industry consideration around 2015. Since safety is integrated into the creation of new capabilities and procedures, safety-related research and development of analysis techniques must yield the analytical tools and methods by 2012 to assess the operational changes planned as part of NextGen.

Layered Adaptive Security

In consonance with the National Strategy for Aviation Security, NextGen will begin by transitioning to integrated management of security risk. An integrated contingency management capability by 2012 will flow from research into specific measures. Starting about 2015, the risk management approach will guide the selection of adaptable new capabilities emerging from research into securing passengers, cargo, airports, aircraft and, airspace.

Environmental Management Framework

The primary environmental constraints on the capacity and flexibility of NextGen are community noise, local air quality, global climate impacts, water quality, and energy production and consumption. The NextGen Environmental Management Framework must also account for interdependencies among many environmental issues, so that in addressing some, others are not exacerbated, while ensuring aviation safety, national security, and economic well being. Goals to triple the air traffic capacity depend on the ability to dramatically reduce current levels of aircraft noise, emissions, energy use, and water pollutants. Significant improvements in both vehicles and operations will be required to achieve these goals. Advancements in technology and aircraft operation, more environmentally sustainable air traffic management procedures, and sound environmental practices at airports will also be necessary to counter the environmental pressures on various segments of the national airspace system.

Net-Centric Infrastructure Services

The net-centric environment begins with the definition of core services by 2010. Once the services have been defined, requirements for digital exchange of data can be established to replace current point-to-point and verbal communication among stakeholders. The major tradeoffs will determine the need for information timeliness, accuracy, and consistency for each decision-maker. The tools generated must support exchanges that span from planning to real-time operations, and must include ground-ground coordination as well as air-ground coordination. By 2014 the research will establish the information management services to support a comprehensive representation of all 4DT negotiations in progress, flight objects, weather, navigation and surveillance data, and airport and air navigation facility operational data.

Positioning, Navigation, and Timing Services

The evolution of Positioning, Navigation, and Timing (PNT) services required to support NextGen will involve development of a national PNT architecture with support from contributing agencies and the National Space Based PNT Coordination Office (NCO) to establish joint programs to provide the necessary infrastructure for NextGen PNT. The primary PNT service provider system of NextGen is a Global Navigation Satellite System (GNSS). In the event of a systemwide or localized loss of signal, a backup system will be required. The strategy for determining what this will be and when it must be in place is an ongoing effort that will require conclusion by 2010 in order to allow equipage transition by 2025.

In addition to users being dependent on space-based PNT sources, the national architecture also recommends use of terrestrial and autonomous sources integrated with space-based PNT to provide robustness in electromagnetically impeded environments. The National PNT Architecture also acknowledges that specialized solutions will continue to exist where it is either inefficient or inappropriate to provide the required capability more commonly. This applies to providing capabilities for the most stringent precision approach (CAT-III) and low-visibility surface operations; R&D should be conducted to define such needs and determine how best to meet them.

Surveillance Services

The major research topic will be the tradeoffs to determine the available sources of surveillance data and their appropriateness in terms of accuracy and timeliness for different operator and facility functions. The research will identify the needs for both cooperative and noncooperative surveillance for security and air traffic management to enable investment decisions by 2014.

APPENDIX B – LIST OF ACRONYMS

Acronym	Definition
4D	Four-dimensional
4D-ASAS	Four-dimensional Airborne Separation Assistance System
4D-FMS	Four-dimensional Flight Management System
4DT	Four-dimensional Trajectory
AAC	Advanced Automation Concept
ADS-B	Automatic Dependent Surveillance-Broadcast
ANS	Air Navigation Support
ANSP	Air Navigation Service Provider
AOC	Airport Operations Center
ARMD	Aeronautics Research Mission Directorate (NASA)
ASDO	Airspace Super Density Operations
ASP	Airspace Systems Program
ATC	Air Traffic Control
ATM	Air Traffic Management
ATOS	Airspace and Traffic Operations Simulation
CAT II/III	Category II/III Instrument Landing System approach criteria
C-ATM	Collaborative Air Traffic Management
CDA	Continuous Descent Arrival
CDM	Collaborative Decision Making
CM	Capacity Management
CNS	Communications, Navigation, and Surveillance
ConOps	Concept of Operations
CTA	Controlled Time of Arrival
DAC	Dynamic Airspace Configuration
DataComm	Data Communications
DST	Decision Support Tool
EDA	En route Descent Advisor
EMS	Environmental Management System
FAA	Federal Aviation Administration
FACET	Future ATM Concepts Evaluation Tool
FCM	Flow Contingency Management
FIS-B	Flight Information Service - Broadcast
FMS	Flight Management System
FOCs	Flight Operations Center
FY	Fiscal Year
GNSS	Global Navigation Satellite System
IMC	Instrument Meteorological Conditions
IOC	Initial Operating Capability
IPT	Integrated Product Team
IWP	Integrated Work Plan
JPDO	Joint Planning and Development Office
LNG	Low-noise Guidance
NAS	National Airspace System
NASA	National Aeronautics and Space Administration

Acronym	Definition
NCO	National Space Based PNT Coordination Office
NextGen	Next Generation Air Transportation System
NGATS	Next Generation Air Transportation System (now NextGen)
NNEW	NextGen Network-Enabled Weather
NRA	NASA Research Announcement
OEP	Operational Evolution Partnership
OI	Operational Improvement
OMB	Office of Management and Budget
OPR	Office of Primary Responsibility
PARR	Problem Analysis, Resolution, and Ranking (MITRE)
PBO	Performance Based Operations
PBS	Performance Based Services
PNT	Positioning, Navigation, and Timing
R&D	Research and Development
RCP	Required Communication Performance
RFA	Research Focus Area
RNAV	Area Navigation
RNP	Required Navigation Performance
RSP	Required Surveillance Performance
RTSP	Required Total System Performance
SA	Separation Assurance
SDO	Super-density Operations
SLDAST	System Level Design, Analysis and Simulation Tools
SMS	Safety Management System
SOA	State of the Art
SSA	Shared Situational Awareness
SUA	Special Use Airspace
SWIM	System-Wide Information Management
TBO	Trajectory Based Operations
TFM	Traffic Flow Management
TIS-B	Traffic Information Service - Broadcast
TM	Trajectory Management
TMA	Traffic Management Advisor
TP	Trajectory Prediction
TPSU	Trajectory Prediction, Synthesis and Uncertainty
UAS	Uncrewed Aerial System
URET	User Request Evaluation Tool
U.S.	United States (of America)
VFR	Visual Flight Rules
Wx	Weather

APPENDIX C – BIBLIOGRAPHY

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14. ABSTRACT
This report describes the alignment of activities of the ATM-Airspace Project, one of two elements of the NASA Airspace Systems Program, with the R&D needs established in the Next Generation Air Transportation System (NextGen) R&D Plan and the NextGen Integrated Work Plan (IWP).

The research focus areas (RFAs) of the ATM-Airspace Project were analyzed with respect to the NextGen R&D needs. Based on this analysis, this report identifies the NextGen R&D needs that are supported by each RFA, as well as the linkage between the milestones in each RFA and the R&D needs.

It was found that there is close alignment between the project's research activities and the NextGen R&D needs. All of the project's 118 milestones are shown to be directly linked to NextGen R&D needs. Furthermore, by virtue of the fundamental nature of the NASA research, all but two of the milestones support multiple NextGen needs, demonstrating the project's robust applicability.

15. SUBJECT TERMS
Airspace Systems Research, NextGen R&D, Air Traffic Management Research, Next Generation Air Transporation System

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