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Airspace Systems Program

Next Generation Air Transportation System Concepts and Technology Development Project

FY2011-2015 Project Plan

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Airspace Systems Program

NextGen CTD Project

FY 2011-2015 Project Plan

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Outline

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1. NextGen Concepts and Technology Development (CTD) PROJECT PLAN OVERVIEW

1.1 Introduction

1.1.1 Purpose

This document describes the FY2011-2015 plans for the management and execution of the Next Generation Air Transportation System (NextGen) Concepts and Technology Development (CTD) Project within the Airspace System Program (ASP). A Program Plan approved by the Associate Administrator of the Aeronautics Research Mission Directorate (ARMD) covers ASP and its two Projects. The CTD Project Plan is in response to the ASP Plan, and follows the planning guidance established by ASP and the NASA Research and Technology Development Management Requirements 7120.8. The Project Plan discusses the CTD Project within the context of NASA's role in Air Traffic Management (ATM) in support of the Joint Planning and Development Office (JPDO), the Federal Aviation Administration (FAA), and the aviation system industry and its users. The Plan addresses the technical approach of the Project, and the programmatic approach to its management and execution. It defines the responsibilities and activities associated with the planning, tracking, review, and reporting of the Project. The Project Plan is maintained as a configuration-controlled document that is updated at least once per year. The focus of this document is the five-year projection of CTD project activities and milestones. The document was developed in response to guidance from the ASP, as approved by the Associate Administrator of the ARMD, and from guidelines in the *Airspace Systems Program Plan*.

1.1.2 Scope

The CTD project is primarily responsible for facilitating the Research and Development (R&D) through developing and exploring fundamental concepts, algorithms, and technologies to increase throughput of the National Airspace System (NAS) and achieve high efficiency in the use of resources such as airports, en route and terminal airspace. In pursuit of that aim, researchers will develop algorithms, conduct analyses and simulations, identify and define infrastructure requirements, identify and define field test requirements, and conduct field tests.

1.1.3 Background

The role of the ASP in defining and achieving the NextGen vision is established with guidance from the NASA Strategic Plan and the 2010 National Aeronautics R&D Plan. The R&D Plan "lays out high-priority national aeronautics R&D challenges, goals and supporting objectives to guide the conduct of U.S. aeronautics R&D activities through 2020." The technical content within the ASP directly supports the needs identified in this National Plan, and provides a strategy to enable the stable and long-term fundamental research necessary to achieve the advances and breakthroughs.

In order to achieve revolutionary improvements, the ASP has taken a leadership role in NASA's partnership with other agencies supporting the JPDO. The JPDO has outlined the vision of NextGen by developing a Concept of Operations (ConOps), an Integrated Work Plan (IWP) and an Enterprise Architecture (EA) to achieve the NextGen vision. ASP research is focused on achieving the vision of NextGen including; accommodating projected growth in air traffic while preserving and enhancing safety; providing all airspace system users more flexibility and efficiency in the use of airports, airspace and aircraft; meeting our civil aviation, national defense, and homeland security needs as a national priority; and maintaining pace with a continually evolving scientific and technical environment.

In FY2010, the Program restructured its two projects to improve the focus on concept and technology transitions from foundational research to systems applications:

- The fundamental Research Focus Areas (RFAs) from the original Airspace and Airportal Projects were consolidated into the NextGen CTD Project. The Project develops and explores fundamental concepts, algorithms, and technologies to increase throughput of the NAS and achieve high efficiency in the use of resources such as airports, en route and terminal airspace.

- The crosscutting RFAs from the Airspace and Airportal Projects were consolidated into the NextGen Systems Analysis, Integration and Evaluation (SAIE) Project. The SAIE project is primarily responsible for facilitating the research and development maturation of integrated ASP concepts through evaluation in relevant environments. The Project also conducts collective impact and safety assessments, and cost-benefit analyses, of ASP research products to drive ASP research investment decisions.

1.2 Objectives

1.2.1 Project Goal and Technical Objectives

In support of NASA Strategic Goal 3, the ASP target ARMD Performance Outcome 3.E.2: *By 2016 develop and demonstrate future concept, capabilities, and technologies that will enable major increases in air traffic management effectiveness, flexibility, and efficiency, while maintaining safety, to meet capacity and mobility requirements of the Next Generation Air Transportation System.*

Key objectives of NASA the ASP are to:

- Perform research to enable new aircraft system capabilities and air traffic technology to increase the capacity and mobility of the nation’s air transportation system
- Perform research to maximize operational throughput, predictability, efficiency, flexibility, and access into the airspace system while maintaining safety and environmental protection.
- Explore and develop concepts and integrated solutions to define and assess the allocation of centralized and decentralized automation concepts and technologies necessary for NextGen.

The Program has identified a set of technical challenges that collectively support these key objectives, Appendix A. In support of these Program objectives, the Project addresses several of these technical challenges within its portfolio.

The primary goal of the CTD Project is the R&D development of fundamental concepts, algorithms, and technologies to increase throughput of the NAS and achieve high efficiency in the use of resources such as airports, en route and terminal airspace. The primary technical objectives of the CTD Project to support this goal are to enable significant increases in capacity/throughput and efficiency, while maintaining safety. And this is accomplished along three thrusts:

- Innovative research and new directions
- JPDO NextGen related research and development (within the scope of NASA's core competencies and where NASA is responsible)
- Advance concepts and technologies for stakeholder benefits (with SAIE)

1.2.2 Alignment

The CTD Project is aligned to meet national and agency goals and objectives as described in the Airspace Systems Program Plan. Specifically, CTD will contribute to the research in the areas of fundamental research in NextGen concepts and technologies in the lower Technology Readiness Levels (TRLs) and transitioning these from the CTD to the SAIE portfolio towards higher TRL. Achieving these program goals will provide transition paths for the program's concept and technology research directly addressing the JPDO Operational Improvements (OI's) or R&D needs, as well as addressing stakeholder needs of advancing technologies to higher readiness levels.

As in previous years under the NextGen-Airspace Project, the NextGen CTD Project research and technology agenda is aligned with the NextGen research needs, commitments, efforts, and resources as defined by the JPDO in the *Next Generation Air Transportation System Integrated Work Plan: A Functional Outline*, the Project will conduct research activities in FY2011-2015 according to that agenda.[1]

1.3 Technical Approach

The NextGen CTD Project conducts foundational research and technology development to extend the state of the art of ATM using aeronautical engineering, computer science, software engineering, applied physics, mathematics, and human factors/automation design and disciplines. The NextGen CTD Project research is tightly coupled with research in the NextGen SAIE Project, and both projects are aligned with NextGen goals and objectives, as defined by the JPDO.

The Project is organized along a series of technical challenges, which have been developed to address barriers in today's NAS. These challenges support NextGen R&D needs as captured in the JPDO's IWP. Within the RFA "research threads" provide progressively more robust solutions toward a technical challenge and the Project tracks progress in each research thread. For a list of major technical challenges identified in late 2010, see Appendix A.

[1] NASA's Aeronautics Research in Support of NextGen, Akbar Sultan, Technical Integration Manager, CTD Systems Program, April 10, 2008.

1.3.1 Research Focus Areas (RFAs)

The NextGen CTD Project is conducting research and development on the efficient utilization of emerging ground, airborne, and space-based technologies to enable NextGen. Accordingly, researchers at NASA Ames Research Center (ARC), NASA Langley Research Center (LaRC) and researchers in the external community at universities and in industry are developing, testing, simulating, and (where appropriate) demonstrating advanced concepts, capabilities, and technologies. The work is organized into the following RFAs:

- **Dynamic Airspace Configuration (DAC)** research is focused on a new operational paradigm in ATM that seeks to modify static airspace resources (controllers/structure) by temporally increasing capacity based on the movement of resources. DAC works with Traffic Flow Management to address the demand/capacity imbalance problem in the safest, most equitable and efficient manner possible.

- **Traffic Flow Management (TFM)** research is focused on the planning (e.g., scheduling and routing) of air traffic flows subject to airport and airspace capacity constraints while accommodating user preferences in the presence of system uncertainties.

- **Separation Assurance (SA)** research is addressing airspace capacity barriers arising from human workload issues related to responsibility for maintaining separation assurance using ground-based and airborne concepts and technologies for transition and cruise airspace.

- **Super Density Operations (SDO)** research is addressing airspace capacity barriers due to human workload/responsibility for separation assurance by utilizing simultaneous sequencing, spacing, merging, and de-confliction for terminal airspace with nearby runway thresholds and arrival/departures runway balancing.

- **Safe and Efficient Surface Operations (SESO)** research is focused on managing traffic on the airport surface (gates, taxiways, and runways) safely and efficiently to enable maximum throughput in the airport environment with consideration of environmental impacts.

1.3.2 Dynamic Airspace Configuration (DAC)

ATM employs capacity and demand management techniques to predict and mitigate air traffic demand/capacity mismatches and balance capacity with demand. In NextGen, as defined by the JPDO, demand management will be allocated to the TFM function; in contrast, capacity management will be allocated, in part, to the DAC function. Effectively functioning in a complementary fashion, DAC and TFM thus represent a new operational paradigm in ATM.

Unlike today's NAS, which is characterized by limited user access to information about airspace status and routine imposition of flow restrictions and/or route amendments on users, NextGen is expected to improve customer service with open access to ATM information and fewer restrictions on, and amendments to, user requests. The primary goal of DAC is to better serve users' needs by tailoring the availability and capacity of the airspace and promptly communicating its status to users. The fundamental objective of DAC is to provide *1) flexibility where possible* and *2) structure where necessary, via strategic airspace organization and* *dynamic airspace, adjustments in response to changing demand*. The DAC input is a set of regularly updated trajectory projections and demand equipage characteristics. DAC is expected to include the following capabilities:

- Temporarily instantiate high-density airspace corridors, low-density general-use zones and/or any other class of airspace to best service aggregate user demand.
- "Flex" airspace boundaries to balance projected airspace complexity.
- Temporarily restrict airspace access based upon performance standards to more effectively ration oversubscribed resources.
- Provide flexibility to users where possible.

The enabler of DAC is a new NAS infrastructure that supports 1) flexible staffing of the NAS, and 2) accurate projections of demand trajectories and equipage. The primary output of DAC will be a reconfigured airspace structure tuned, to the extent feasible, to accommodate aggregate user demand. The time horizon within which traffic managers could be expected to reconfigure airspace will range from months, to days, to hours, as needed.

1.3.3 Traffic Flow Management (TFM)

The primary function of Traffic Flow Management (TFM) is to identify and resolve any imbalance(s) in the demand and supply of NAS resources, such as airspace and runways. The TFM function in NextGen has to be designed to accommodate future traffic growth, while accounting for system uncertainties, and accommodating user preferences. To accomplish this goal, the TFM effort is organized into three focus areas: (a) Traffic Flow Optimization, (b) Collaborative Traffic Flow Management (CTFM), and (c) Weather Impact Assessment.

The traffic flow optimization area focuses on developing linear and nonlinear optimization techniques, as well as, heuristic-based approaches and decomposition methods for effectively developing aircraft-level or aggregate flow control strategies in response to actual and predictive demand and capacity imbalances at the local, regional, and national levels. These optimization techniques contribute to the goal of increasing NAS capacity by leveraging key features of NextGen such as 4D trajectory-based operations, performance-based operations, automated separation assurance, and super-density operations.

- **Collaborative Traffic Flow Management** in TFM focuses on the development of methodologies for incorporating user preferences into traffic flow management. The outputs of this focus area are algorithms, procedures, and protocols for fully integrating CTFM into the TFM process.
- **The weather impact assessment component** of TFM develops metrics to predict and analyze the performance of the NAS with respect to observed or predictive weather; develops models to translate meteorological observations and forecasts into time-varying deterministic and probabilistic estimates of the available airspace and airport capacities; and defines requirements for NextGen ATM weather products.

The output of the TFM focus area is a set of modeling, simulation, and optimization techniques that are designed to minimize or maximize a system performance measure, such as total delay, subject to airspace and airport capacity constraints while accommodating weather uncertainty, user preferences, and predicted growth in demand.

1.3.4 Separation Assurance (SA)

In today's NAS operations, air traffic controllers provide separation assurance by visual and cognitive analysis of a traffic display and by issuing control clearances to pilots using voice communication. Decision support tools (DST) deployed in recent years provide trajectory-based advisory information to assist controllers with conflict detection and resolution, arrival metering, and other tasks. Although DSTs have reduced delays, a human controller's cognitive ability limits his/her ability to handle more than approximately 15 aircraft. Consequently, a fundamental transformation of the way separation assurance is provided is necessary in order to achieve NextGen 2025 performance objectives. Emerging aircraft performance capabilities are expected to play a key role in NextGen operations. The objective of SA research in the NextGen CTD Project is to identify trajectory-based technologies and human/machine operating concepts capable of safely supporting a substantial increase in capacity (e.g., 2-3X) under nominal and failure recovery operations, while accommodating airspace user preferences and favorable cost/benefit ratios. SA research in the NextGen CTD Project is focusing on three areas:

- **Automated separation assurance technology development.** Researchers are focusing on 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 huge variety of traffic conditions in the NAS.

- **Functional allocation research.** Researchers are developing human/machine air/ground allocations to provide integrated solutions for traffic conflicts, metering and weather (Wx) avoidance. This will include a series of human-in-the-loop simulations (HITLs) of increasing complexity with higher traffic densities, mixed equipage/operations in nominal and off-nominal conditions.

- **Human/automation operating concepts research.** Researchers are addressing the need to conduct analyses of cognitive workload, situational awareness, performance under different service-provider-based concepts of operations, roles, and responsibilities of controllers and pilots and include a series of human-in-the-loop simulations of increasing complexity and fidelity.

- **System safety and failure recovery analysis research.** Researchers are addressing the need to identify 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.

1.3.5 Super-Density Operations (SDO)

SDO refers to highly efficient operations at the busiest airports and in the terminal airspace. Capacity at the busiest airports plays a key role in determining the efficiency and robustness of the NAS and ultimately defines the attainable growth in air traffic. Significant growth at the busiest airports as well as regional and smaller airports is needed to achieve NextGen capacity goals. The JPDO envisions a combination of new technologies enabling significant growth at large airports and increased operations at underutilized airports to absorb the expected increase. Increasing capacity in the current architecture is not scalable to meet future needs. A new operational paradigm is needed to increase terminal area capacity to meet NextGen demand. To support this goal, the NextGen CTD Project is conducting SDO research in the following areas:

- **Concept of operations development** is focused on employing rapid prototyping and fast-time simulation to assess and iteratively refine the concept of operations based on improved understanding of the fundamental challenges and development of enabling technologies to address those challenges.

- **Sequencing and deconfliction technologies development** is focused on advancing sequencing and deconfliction methods beyond the current practices of modified first-come-first-served scheduling and tactical separation service. Outputs of this research will be an understanding of the inherent uncertainty associated with execution of precision trajectories in SDO airspace together with improvements in multi-objective constraint optimization for air traffic systems.

- **Precision spacing and merging technologies development** is addressing the need to reduce the level of uncertainty inherent in aircraft operations in SDO airspace and enable many aspects of Equivalent Visual Operations, a key capability associated with NextGen, as defined by the JPDO. This research will produce procedures and technologies for airborne precision merging and spacing extended to meet multiple constraints and environmental considerations.

- **Regional SDO resource optimization research** is defining methods for regional resource optimization to enhance regional SDO capacity and robustness to a variety of disturbances. Outputs will include methods for managing precision and non-precision operations in the same airspace. Work will be coordinated with performance based systems research to incorporate precision performance-based concepts in SDO airspace.

- **Concepts and technologies for runway balancing and assignment for arrival/departures** will be developed. As appropriate these will be integrated with scheduling and surface management technologies. Limitations due to wake, location and strength will be particularly considered for dynamic wake spacing.

1.3.6 Safe and Efficient Surface Operations (SESO)

SESO research is investigating new technologies and concepts to increase airport capacity by enhancing the flexibility and efficiency of surface operations. The research will result in evaluations of integrated automation technologies and procedures designed to provide the following capabilities:

- **Improved surface traffic planning** through: 1) balanced runway usage; 2) optimized taxi planning of departures and arrivals; 3) departure scheduling satisfying environmental constraints, dynamic wake vortex separation criteria, and constraints driven by other NAS domains; and 4) balanced runway usage and efficient runway configuration management through coordination with SDO. Environmental impacts will be considered as concepts are investigated.

- **Providing the capability of trajectory-based surface operations** by modeling of aircraft surface trajectory prediction and synthesis, developing pilot display requirements and technologies for 4D taxi clearances compliance, and taxi clearance conformance monitoring algorithms and procedures.

- **Maintaining safety in ground operations** through the development of concepts and algorithms for both aircraft- and ground-based surface conflict detection and resolution (CD&R) and integration of the two approaches. This research will be done in coordination with the Integrated Intelligent Flight Deck (IIFD) Project in the Aviation Safety Program. The IIFD Project and NextGen CTD Project will work on flight deck technologies for surface CD&R and collaborate in the development of requirements for the display characteristics of these technologies for flight crews.

Researchers will develop surface traffic simulation capabilities (fast- and real-time simulation with human-in-the-loop) and a surface traffic data analysis tool, then will use them to evaluate integrated technologies. A software interface will also be developed to integrate the real-time surface traffic simulation with flight deck simulation capabilities.

1.3.7 Milestones

The complete list of milestones defined by the Project is provided in Appendix B and include the following:

- B-1. Legacy Milestones FY2007 – FY 2010

- B-2. Current Milestones FY2011 – FY2015

- B-3. Milestone Schedule FY2011 – FY2015

- B-4. Key Milestones FY2011 – FY2012

By the end of the current 5-year plan, research results will provide information for design guidance for further research and development. Over the duration of the project, validated algorithms and prototype technologies that support the JPDO vision and capacity goals will be transitioned to SAIE for further development and future transition to the FAA and industry. Details of the near-term technical work planned for FY11 are addressed in the Project's Milestone Records (Appendix C).

2. PROJECT IMPLEMENTATION

2.1 Resources

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2.1.1 Full-Time Equivalent (FTE) and Work-Year Equivalent (WYE)

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2.1.2 Procurement

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2.1.3 Facilities and Laboratories

NASA facilities and laboratories will be utilized extensively in FY2011 for project research. A listing, of which facilities will be used for specific milestones, as well as descriptions of the major laboratories, can be found in Appendix E.

2.2 Management

2.2.1 Organizational Structure

Beginning in FY11, a new project governance model was instituted, as presented in Appendix F. The CTD Project management structure consists of a Project Manager (PM), Deputy Project Manager (DPM), Deputy Project Manager for (DPMF) Langley, DPMF Ames, and Project Scientist (PS). The current management structure is documented in Appendix F.

The PM is responsible and accountable to the ASP Program Director (PD) for the technical objectives and content of the Project, and for the planning and execution of the Project.

The DPM is responsible and accountable to the PM for developing the Project Plan, and for overseeing the execution of the project, with primary responsibility for project fiscal performance.

The DPMFs are responsible and accountable to the PM for technical content and Milestone Record contract execution within each research focus area, along with monitoring budgetary performance at their respective Centers.

The PS is responsible and accountable to the PM for the technical content, integrity, innovativeness, and long-term vision of the Project, and ensures that the highest technical standards are exhibited by the Project.

The management team is supported by a group of research and programmatic professionals at each Center.

Each of the five RFAs are guided by Technical Leads (TLs) ensure the executed work addresses the technical challenge(s). The TL will who work closely with the DPMFs, who are accountable for the execution of the relevant Milestone Record contracts, across the Centers, for their respective RFAs.

2.2.2 Project Reporting and Reviews

Reporting and reviews for the Project include scheduled telecons, and internal and external technical peer reviews. Specific examples of project reporting and reviewing requirements are presented below:

Reporting:

- Bi-weekly project telecons that include the PM, DPM, DPMFs, PS, TLs, and other Project support staff as required. Project-related near-term and strategic planning, issues, and actions are discussed during these telecons.
- Weekly ASP telecons with Program Office staff that include participation of the PM, DPM, DPMFs, and PS. In addition, Center Point Of Contacts (POCs) and supporting Research Managers (RMs) are invited to participate. Program-level strategic issues and near-term actions are discussed during these telecons.
- Bi-monthly ASP business telecons with the ASP Program Integration Manager (PIM) that include participation of the DPMs, DPMFs, and Resource Analysts from SAIE and CTD. Program-level business issues and reporting are covered during these telecons.
- Weekly CTD business team telecons that include participation of the CTD DPM, DPMFs, and Resource Analysts. Project and Program-level business issues and reporting are covered during these telecons.
- Quarterly reports, submitted to the Program office by the DPM, with input from the DPMFs, answer key State-of-the-Agency (SOA) questions that monitor the programmatic status of the project
- Weekly Project status reports are provided to Ames Center management. These reports are distributed to the Program Office and to Center POCs. The weekly report is presented by the PM, DPM, or DPMF in an Ames Center stand-up every 5-6 weeks.
- The PM, DPM, and PS from the SAIE and CTD Projects meet periodically to discuss common issues and inter-Project coordination and collaboration. Technical planning and coordination between Project TLs will be conducted as required.

Reviews:

- ARMD year-end Program reviews are conducted. As part of the ASP review, the CTD Project is presented by the PM to the ARMD Associate Administrator (AA) directly.
- Technical peer reviews (internal and/or external) are held annually. ASP and ARMD determine the schedule for, and the content of, these reviews.
- Both Centers conduct quarterly Center Management Council (CMC) reviews of the SAIE and CTD Projects, at which the PM, DPM, or DPMF present the programmatic status of the Project. The PD and Center POCs are invited to participate in all CMC reviews, and copies of slides are distributed to them as well.
- Technical Integration Meetings (TIMs) are held every 12-18 months. Researchers from both SAIE and CTD present their research findings to a broad audience, including the FAA and JPDO, and stakeholders from industry and among users of the airspace system. Significant technical interaction occurs at these TIMs, with special sessions specifically designed to interact with the stakeholder community to obtain their feedback and input to NASA-developed concepts and technologies.

2.3 Controls and Change Process

The processes for documenting milestone completion and for change control in ASP and its Projects are hierarchical. The ASP Program Plan is the agreement and top-level document that describes the program, and is the controlling document for program content and management. The Program Plan is submitted by the PD to the ARMD AA for approval. The CTD Project Plan is the agreement between the PM, DPM, CD/POCs, and the PD for ASP. (The Project Plan documents technical plans, milestones, deliverables, schedules, resource management approach, etc., to ensure successful delivery of technical products to ASP. Milestone completion constitutes the delivery of technical products from the DPMF and TL to the PM and, in the case of key milestones, the PD.)

2.3.1 NextGen CTD Project Milestone Change

The process for documenting concurrence and approval of a milestone change is as follows:

The Milestone Change Request (MCR) will document the DPMF's request to the PM for approval to change any one or more of the following elements of a milestone:

- Title or description
- Start or end date
- Slip of more than one quarter within the fiscal year or any slip from one fiscal year to the next.
- Dependencies
- Deliverables
- Metric
- Exit Criteria
- Other [as determined by the TL/DPMF]
- Reason for change
- Description of change
- Impact of change

The TL and the DPMF will develop the MCR jointly. It will be coordinated with the PS, and submitted to the PM for approval. If the milestone is a Key Milestone, supports an Annual Performance Goal (APG), or supports a High Priority Performance Goal (HPPG), the PM will obtain the Program Director's approval for the change. Once the form is signed off, it will go to the DPM, who will assign a milestone change control number. A copy of the MCR will then be provided to the Scheduler for any adjustment to the schedule.

2.3.2 NextGen CTD Project Milestone Completion

The process for documenting concurrence and approval of milestone completion is:

1. The Milestone Completion Memo (MCM) will document the completion of any milestone. It will be submitted by the DPMF to the PM and will briefly describe the following:
   - Exit Criteria, and how it was met
   - Metric met. If not fully met, what part of the metric was met and what is the anticipated impact of not fully meeting?
2. Applicable reports or supporting documentation will be attached to the memo. (e.g., technical report, simulation report, briefing charts)
3. Any additional information the TL might want to provide should be attached to the memo.

The DPMF and the TL will develop the MCM jointly. It will be coordinated with the PS, and submitted to the PM for approval.

If the milestone is a Key Milestone, or supports an APG or HPPG, the PM will obtain the PD's concurrence in the acceptance of the completion of the milestone. In addition, a two page PowerPoint explanation of the results will also be required.

Once the MCM is signed off, it will go to the DPM for archive. A copy of the memo will then be provided to the Scheduler for any adjustment to the schedule.

2.4 Work Breakdown Structure

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2.5 Risk Management

CTD utilizes the NASA Continuous Risk Management process as its approach to risk management. As part of the Project's approach to managing risk, the Project developed a Risk Management process, in 2007. The Project will consider its approach to managing risk to be successful if DPMFs and the Risk Manager accomplish the identification and resolution of risk issues prior to impact on research tasks or project outcomes. As an enhancement to this process, the Project also tracks technical risk by milestone. Research findings sometimes indicate original milestone schedules or deliverables are inconsistent with desired outcomes. Milestones at risk of delay, or not delivering on original metrics are tracked in a similar manner as the project or program management risks. While tracking technical risks, the Risk Manager will conduct monthly risk meetings to track progress, and to provide assistance with risk mitigation to enhance the likelihood of successful outcomes.

2.6 Acquisition Strategy

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2.7 Partnerships and Agreements

2.7.1 NextGen CTD-SAIE Interface

The successful transition of concepts and technologies to stakeholders depends on the SAIE and CTD Projects working in a coordinated manner. To facilitate this transition, the two projects have identified roles based on TRL, likely transition paths that concepts or technologies may find themselves on, Research Transition Teams to conduct transition activities, the actual coordination strategy that CTD and SAIE Projects utilize, and a plan to evaluate pop-up ideas or unexpected research opportunities.

TRL responsibilities between the projects follows closely with the Projects' primary roles (see Appendix I). The CTD project is the lead project for lower TRL (TRL 1-3) activities. At TRL 4, the projects work together as research responsibility shifts from CTD to SAIE. SAIE leads activities at TRL 5-6. Those technologies that have work tasks at the TRL 1-3 are handled by CTD. TRL 4 work will be handled by the appropriate project based on the work documented in the milestone and milestone records.

At TRL 7, there are additional partners in prototype demonstration and again the projects work together with the designated stakeholders for best success. Activities beyond TRL 7 include implementation into operational environments, and neither project will have lead responsibilities for these activities. At this level of readiness, stakeholders take responsibility for implementation, and NASA projects serve as consulting subject matter experts depending on agreements between stakeholder and the Program/Projects.

Research transition paths to stakeholders vary depending on the type of product and/or interest of the stakeholder. Activities include integrated concepts/technologies that require complex, high fidelity simulations, interoperability/interactions considerations, and involvement of multiple RFA items/concepts/technologies. Other areas involving both projects include testbed demonstrations and field tests at appropriate sites. Demonstrations in testbeds have been discussed with the FAA as a stakeholder. The NASA NTX testbed will facilitate appropriate demonstrations either independently or in the future, in conjunction with the FAA testbed under development. Field tests will identify appropriate environments to use and may include FAA field sites such as Air Route Traffic Control Centers (ARTCC, or "Centers"), Terminal Radar Approach Control (TRACON) facilities, and Air Traffic Control Towers (ATCT, or "Tower").

In the second transition path, SAIE transitions a product to an external stakeholder directly. Tools or technologies being developed by SAIE and made available to stakeholders transition directly to the stakeholder. Analysis being conducted may also be conducted with or leveraged directly by stakeholders based on coordination or agreement. A key stakeholder for these types of products is the JPDO's Interagency Portfolio and System Analysis (IPSA) division.

In the third transition path, CTD transitions a product to an external stakeholder directly. This is usually a low TRL product that may have been defined by a stakeholder's eagerness to transition at an early TRL, a stakeholder's need for early decision making; or a stand-alone item, in which the stakeholder performs the integration into an existing system, and not requiring any NASA integration activities.

The various transition modes available demand that CTD-SAIE have a coordination strategy to keep foundational research unencumbered and still ensure that the research has a maturation and transition path to stakeholders. In order to accomplish this, CTD and SAIE will work together to accelerate high impact products based on stakeholder interests. Products include technologies, concepts, algorithms, prototypes, or knowledge such as functional allocation. CTD is concentrated on individual concept and technology development with a deeper focus. SAIE is focused on system-level, integration, and technology transition considerations with a broader emphasis. In each case, specific understanding between CTD and SAIE needs to be developed. Each technology or concept is likely to have differing needs and different involvements. Activities requiring joint efforts are defined by both Projects' PM/DPM/PS. During the course of normal project development CTD and SAIE will negotiate how the collaboration will be handled year to year based on the unique requirements of the current concepts and technologies development phase they are in. This collaboration will be documented in the milestones and the associated milestone records for the upcoming year.

Research Transition Teams (RTTs), jointly established with the FAA, have been implemented to help identify research and development needed for NextGen implementation and to ensure that the research is conducted and effectively transitioned to the implementing agency. The SAIE and CTD projects are currently supporting the following RTTs, jointly with the FAA:

- **Efficient Flow into Congested Airspace (EFICA)** is the responsibility of the SAIE project and focuses on a few key technologies in the dense arrival/departure area such as merging and spacing including work with FAA's ATO-P and SBS office, Efficient Descent Advisor, including field test at FAA's Denver Center.

- **Flow-based Trajectory Management (FBTM)** is the responsibility of the SAIE project and focuses on identifying the feasibility and benefits of the Multi-sector Planner concept. This is a concept study with human in the loop simulations for demonstration to FAA.
- **Integrated Arrival/Departure Surface (IADS**) is the responsibility of the SAIE project and includes research from the CTD project. It includes the Precision Departure Release Capability that will conduct testbed studies at NASA's North Texas (NTX) facility. Also, the airport surface optimization is scheduled to conduct similar studies at NTX in the near future.
- **Dynamic Airspace Configuration (DAC)** RTT remains the responsibility of the CTD Project being long-term focused research.

The Projects are continually engaged in efforts to identify new research opportunities both internal and external to the Program. These opportunities are anticipated to present themselves from time to time, and the following process has been defined to properly evaluate these opportunities, and to potentially integrate them into the Program portfolio of activities:

- CTD/SAIE PM/PS/DPM and involved researcher(s) meet to discuss the idea. The Project team prepares the proposal to the Program with three options; pursue, don't pursue, or more information/base work/analysis is needed before decision. "Seedling" and other possible sources of funding are explored.
- Host Center management and partner Center POCs and/or designees will be involved throughout the process.
- Program will make the final decision based on committee/board input.

2.7.2 Partnerships

The CTD Project will seek partnerships with industry, universities, JPDO, and other government agencies in research related to SAIE goals and objectives. Early involvement of these entities, combined with frequent input, will be necessary throughout the development and validation of the NextGen concepts and research. The development of system-level capabilities and integrated systems is a high TRL effort that is appropriate for collaboration with industry partners and other government agencies. CTD will consider the following when assessing potential collaborations:

- Collaborations are established only when there is significant benefit to NASA and its constituencies (aerospace community, aerospace industry, academia, and ultimately the U.S. tax-payer).
- Once the collaboration is established, the results can be appropriately disseminated and validated through a peer-review process.

Additional guidelines to be considered:

- Is the collaboration suitable for NASA to pursue?
- Does the collaboration help advance and disseminate knowledge and technology?
- Have we ensured that restrictions for data distribution do not prevent the advancement of knowledge in the specific discipline?

2.8 Research Transition Teams (RTTs)

Research Transition Teams (RTTs), jointly established with the FAA, have been implemented to help identify research and development needed for NextGen implementation and to ensure that the research is conducted and effectively transitioned to the implementing agency. For more details refer back to section 2.7.1.

2.9 Foreign Collaboration

The Airspace Systems Program and its legacy projects actively established participation with foreign organizations to conduct joint ATM research. The NextGen CTD Project is committed to maintaining these efforts, where appropriate, and to identifying new areas of opportunity for foreign collaboration. Existing and new foreign collaborations will be aligned with the five Project RFAs as appropriate.

To facilitate foreign research collaboration, the NextGen CTD Project will follow guidelines for capturing and documenting foreign collaborative research efforts established by the NextGen-Airspace Project. The guidance is in full compliance with the U.S. Department of State's International Traffic in Arms Regulations (ITAR) and the U.S. Department of Commerce's Export Administration Regulations (EAR). Titled, "NextGen-Airportal Project Guidance on Foreign Collaboration," the guidance document is tailored to NextGen ATM research and will serve as a template for current and future collaborative research. Rather than inhibit or discourage foreign research collaboration, the guidance is intended to facilitate and encourage collaboration where it can be demonstrated that the collaboration will add value to Project, Program, and ARMD mission, goals, and/or objectives.

The TL in each RFA is empowered with, and responsible for, identifying new opportunities for foreign collaboration and, along with the DPMF(s), for managing existing and new foreign research collaboration. The TL and DPMF(s) will coordinate with both project and line management. A formal review and approval process has been developed for use in evaluating foreign collaboration proposals for consistency with Project, Program, and ARMD mission, goals, and/or objectives. Questions that must be adequately addressed by the TL and the DPMF(s) include, but are not limited to, the following:

- Is there a formal charter for the proposed research that delineates tasks, responsibilities, and time period?
- What vehicle will be utilized for the formal agreement (e.g., Action Plan, Letter of Authorization, Memorandum of Authorization)?
- What are the respective responsibilities between NASA and the relevant foreign organization(s)?
- Which organization(s) are responsible for assigning and managing research tasks?
- What amount of effort is required to fulfill the duties (e.g., preparation, travel, meetings)?
- Will the conduct of the foreign research impact the completion of any NextGen CTD Project milestones?
- Is the research directly related to any Project milestones? If so, which milestone(s) are related?
- Does the research provide an advantage to foreign companies at the expense of the U.S. taxpayers? If the answer is no, why not?

- How will the performing organization(s) accommodate new requests for additional or follow-up research?
- Who will approve additional or follow-up research?

The TL shall address these questions in a letter of interest and submit it to the PM for formal approval of the proposed foreign collaboration. The TL should allow 30 days for Project Office and Program review and approval or rejection. Once an agreement is in place, the TL will be responsible for managing foreign collaboration research.

2.10 Knowledge Dissemination

The CTD Project will disseminate research results to the greatest extent practicable, in as timely a manner as possible. The quality of the technical work performed in the Project will be assessed against milestone metrics through informal and formal CTD management reviews, and peer internal and external reviews. Technical publications, peer-reviewed journal articles, and invited papers and presentations will quantify the level of technical dissemination of CTD research. This strategy aligns with the ARMD objective of advancing knowledge in the fundamental disciplines of aeronautics, and is in keeping with the Space Act of 1958 that requires NASA to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."[2]

Future programs and projects benefit from the knowledge and understanding gained during the formulation, implementation, and execution of past and current programs and projects. Lessons learned will be documented and shared with other ARMD projects. Documented lessons learned, when appropriate, will be shared with Center and Headquarters' Systems Management Office or Chief Engineer's Office and the ARD front office.

A summary table of the FY2010 knowledge dissemination as of the FY10 Annual review is located in Appendix K for reference.

3. Milestone Records (Task Planning)

Milestone Records document the detailed requirements, work, resources, labs, major facilities, and task deliverables, to conduct CTD research in the upcoming fiscal year. The TLs and DPMFs, working with RMs and facility managers, develop task plans for their respective RFAs within the Milestone Records. Milestone Records are contracts between the DPMFs, RMs, and the PM. Updated task planning for the upcoming fiscal year takes place during the 3rd and 4th quarters of the current fiscal year.

Coordination between the CTD and SAIE Projects in year-to-year planning is critical to the success of the two projects, and forms a cornerstone of their planning and research efforts.

Milestone records for each RFA are located in Appendix C.

4. APPENDICES

Appendix A. Major Technical Challenges

Appendix B. Milestone Tables, Schedule, and Listing

Appendix C. FY2010 Milestone Record Activity

Appendix D. NextGen CTD Resources

Appendix E. NASA Facilities and Laboratories

Appendix F. Project Management Structure

Appendix G. FY2011 CTD Project Work Breakdown Structure

Appendix H. Awarded NRA Tasks

Appendix I. TRL Responsibilities between the Projects

Appendix J. Formal Agreements

Appendix K. Knowledge Dissemination

Appendix L. Milestone Change Table

Appendix M. Review Comments and Discussion

Appendix N. Acronyms and Abbreviations

Appendix O. Waivers and Deviation Log

Appendix P. Change Log

Appendix A. Major Technical Challenges

Major technical challenges most recently identified in late 2010.

Responsible Project	Title	Description
CTD	Efficient Arrival Operations	With limited decision support, air traffic controllers rely on sub-optimal arrival routes and inefficient level-offs to keep aircraft safely separated. Develop new concepts, procedures and algorithms to maximize arrival rates to single airports and metroplexes, while also reducing fuel burn, emissions, and noise. Improved arrival area operations rely on effectively integrating multiple concepts, including high precision scheduling, flight deck merging and spacing, and terminal area (near-airport) conflict detection and resolution.
CTD	Efficient Arrival/Departure/Surface Operations	Controllers lack decision support systems to strategically plan optimal airport resource use across arrivals, departures, and surface operations. Coordinated scheduling of departing and arriving flights with surface operations improves efficiency and throughput at and near the airport.
CTD	Separation Based on Wake Prediction	Static wake vortex separation standards may lead to lost capacity in some cases. Improve airport capacity through use of dynamic wake vortex standards. Advanced sensors, models, and decision support systems allow controllers to apply appropriate wake separation standards based on aircraft characteristics and atmospheric conditions.
CTD	Optimize NAS Performance and Environmental Protection	Sub-optimal strategic flow management decisions, particularly in the presence of hazardous weather can lead to extensive delays. Develop modeling, simulation and optimization techniques to minimize total system delay (or other performance functions), subject to airspace and airport capacity constraints, while accommodating three times traffic in the presence of uncertainty.
CTD	Minimize Impact of Weather	Traffic flow managers have only limited decision support for planning efficient flows in the presence of weather. Develop strategies, algorithms, and decision support tools that allow traffic flow managers to minimize disruptions caused by hazardous weather. Algorithms incorporate probabilistic weather information, contributing to more accurate and efficient decisions on in-flight weather deviation and ground-delay programs.
CTD	Increase Efficiency through User Collaboration	Air traffic service providers face significant challenges in developing traffic flow strategies that provide system-wide efficiency and user equity. Develop and validate concepts and technologies that meet the needs of diverse stakeholders, under high traffic and severe weather conditions. Advanced models also offer greater flexibility to flight operators and service providers when allocating flights and traffic flows to constrained resources.
CTD	Address Demand/Capacity Imbalance	With limited exceptions, today's airspace sectors are static and cannot support higher capacity. Develop concepts, algorithms, and technologies that allow en route capacity to be allocated as needed to meet demand. Capabilities promote more flexible airspace design and include techniques such as airspace boundary changes and dynamic flow corridors.

Responsible Project	Title	Description
CTD	Optimized Surface Operations	Imprecise surface movement across multiple independent entities and lack of common situation awareness lead to sub-optimal operations. Enable more efficient surface operations that reduce delays and fuel emissions. Concepts and advanced algorithms provide coordinated, optimized trajectory-based paths supported by high precision taxiing and conformance monitoring.
CTD	Improve Safety of Surface Operations	Reducing runway incursions continues to be a high-profile safety need. Provide ground-based and airborne alerting capabilities that mitigate runway incursions and low altitude conflicts, even under high traffic density operations.
CTD	Trajectory-Based Operations Enabled by Conflict Detection and Resolution	Controller workload is generally the limiting factor to increasing en route capacity and allowing wind-optimal trajectories. Explore greater levels of automation support to help mitigate controller workload. Develop separation assurance algorithms for airborne and ground-based systems that detect and resolve traffic conflicts while meeting assigned trajectory constraints, under high traffic density and with uncertainty.
CTD	Safety Assessment for Conflict Detection and Resolution Automation	Safety assessments and certification processes generally rely on comparison between candidate and previously certified systems. Many separation assurance systems under consideration for NextGen bear little resemblance to legacy systems. Working with Aviation Safety Program, develop and evaluate new methods that allow credible safety evaluations of highly complex, automation-intensive systems. Methods contribute to formal validation and verification of separation assurance operational concepts, algorithms, and software code.
CTD/SAIE	Human/Machine, Air/Ground Functional Allocation	En route airspace capacity is limited by today’s ground-based, human-centered separation assurance system. Under NextGen, a greater reliance on automation and/or aircraft capabilities may improve efficiency, while maintaining safety. Support informed NextGen decisions on air/ground and human/automation functional allocation for separation assurance. Comparative studies evaluate different operational concepts and technologies in a variety of trajectory-based operations environments.
SAIE	Relevant Environment Integration and Evaluation	Many NASA technologies could provide benefits to the National Airspace System, yet it’s been difficult to transition them to stakeholders. Improve the potential to transition NASA technologies into the National Airspace System through high-fidelity simulations and flight evaluations. Performance assessments concentrate on technology integration with flight and ground hardware systems, proper functioning in operational environments, and interactions with real-world data sources.

Responsible Project	Title	Description
SAIE	Trajectory Prediction and Interoperability	Tactical heading and altitude changes are frequently used in today's air transportation system. These control strategies lead to large position uncertainties and inefficient operations. Advance NextGen enabling capabilities related to trajectory prediction and interoperability. Improve the accuracy and capabilities of ground-based and airborne trajectory predictors. Develop methods to reliably assess the ability of different trajectory predictors to meet the needs of NextGen applications. Contribute to common protocols for exchanging trajectory information between ground-based and airborne systems.
SAIE	Portfolio Analysis of Integrated System-Level Concepts and Technologies	Program research should focus on areas of high potential for improving system-wide capacity and efficiency. Conduct benefits assessments of single and integrated concepts to support program portfolio investment. Refine concepts to ensure effective interdependent operations across multiple air traffic domains and time horizons. Collaborate with JPDO on system-level studies and development of common metrics and scenarios.
SAIE	Application of New Solutions to Air Traffic Management Challenges	Program research should be infused with innovative approaches for improving system-wide capacity and efficiency. Identify system level demand/capacity imbalances and approximate upper ceiling of potential capacity improvements. Studies explore trends in future aviation demand and compare with operational and physical constraints that limit capacity growth. Exploratory studies consider new approaches toward addressing aviation demand, while respecting system constraints.

Appendix B. Milestone Tables, Schedule, and Listing

Appendix B contains the following milestone documents:

- B-1. Legacy Milestones FY2007 – FY 2010
- B-2. Current Milestones FY2011 – FY2015
- B-3. Milestone Schedule FY2011 – FY2015
- B-4 Key Milestones FY2011 – FY2012

B-1. Legacy Milestones – FY 2007 - FY2010

Appendix B-1 contains legacy milestones for FY2007 – FY2010.

Table 1. Legacy Milestones FY2007 – FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.4.3.01	Critical	Dynamic Airspace Configuration Concepts Experimentally Validated			Frequency of airspace reconfiguration, extent of airspace reconfiguration, system stability measures, amendments and restrictions imposed on users, airspace complexity distribution		Original Cancelled
AS.4.7.01	Critical	Develop Refined System-level Concept of Operations Based on Results of Modeling, Safety, Cost-benefits, and Human-in-the-loop Simulations			A refined concept of operations will be delivered		Original Cancelled
AS.3.1.01	Critical	Develop, Validate, and Document Common Trajectory Model Algorithms and Capabilities for NGATS Applications Within En-Route and Transition Airspace	8		Trajectory accuracy, predictability	Experiment plan for interoperability	Original Cancelled Merged
AS.3.2.01		Produce a List of Candidate NGATS Operational Concepts.	7		NGATS vision mapping gaps		Original Completed
AS.3.2.02	Critical	Produce a Detailed Hierarchical Structure of RTSP Elements and Advanced Performance Measures Needed to Support Candidate NGATS Operational Concepts	8		Organization of performance attributes to map with level of service		Original Cancelled
AS.3.2.03		Working with Industry and JPDO's Shared Situation Awareness IPT, Define the Parameters Associated with RCP and RSP.			Definitions of RCP, RSP, RNP		Original Cancelled Realignment Merged
AS.3.2.04	Critical	Parametric RTSP Batch Studies of AAC and 4D-ASAS Concepts are Completed Under Nominal and Failure Mode Conditions			Capacity, throughput, efficiency, safety, predictability		Original Cancelled Realignment Merged

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
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			Capacity, throughput, efficiency, safety, predictability		Original Cancelled Realignment Merged
AS.3.3.01		Categorize Events that Trigger Airspace Reconfiguration	8		Number of scenarios documented, number of events cataloged.		Original Completed
AS.3.3.02		Develop an Operational Framework for Dynamic Airspace Configuration	8		Breadth and depth of taxonomy of the "building blocks" for airspace configuration and the "degrees of freedom" available to dynamically modify them.		Original Completed
AS.3.3.03	Critical	Identify Complexity Metrics for Higher Levels of Automation and Higher Traffic Densities	8		Binary: milestone completion status		Original Completed
AS.3.3.04	Critical	Airspace Flexibility	9	4	Workload measures per amount and frequency of airspace change. Degree of airspace change.	Publication, white paper or report.	Original Completed
AS.3.3.05		Generic Airspace	10	4	Time to learn sector-specific knowledge, amount of sector-specific knowledge eliminated, effectiveness of methods.	Publication, white paper or report.	Realignment Current Completed
AS.3.4.01	Critical	Develop Traffic Flow Management Concepts at the Regional and National Levels for Different Planning Intervals to Increase Efficiency, Reduce Delays, and Accommodate User Preferences	8		The output of this effort is an integrated set of advanced TFM concepts and the associated algorithms/models that will be integral to the development of the Evaluator.		Completed Original
AS.3.4.02		Early Integrated TFM Concept Definition and Development, Including Initial Concept of Operation Focused on National and Regional TFM for Increasing Flow Management Efficiency and Accommodating User Preferences.	9	4	The output of this effort will be a baseline integrated TFM concept of operations that describes the composition and architecture of TFM functions as well as their temporal and geographic scope.	Conference or white paper describing the early integrated TFM concept definition.	Original Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.3.4.03		Determine User and Service Provider Roles to Accommodate User Preferences and Increase Efficiency	10	4	The product of the milestone will identify the type of decisions that users and service providers should make to promote maximum efficiency, balance workload, and accommodate user preferences. The milestone report will also describe the information needs and exchanges to enable CDM to handle 3x capacity.	Conference or journal publication describing methods or concepts for incorporating user preferences into the traffic flow management decision making process.	Original Current Completed
AS.3.4.04		Expand Traffic Flow Management Concepts to Address Weather Modeling Uncertainty to Promote Higher Predictability and Efficiency	10	4	The outputs of this activity are probabilistic models/algorithms, and weather product requirements, for improved predictions of NAS resource demand/supply under uncertainty.	a. A conference and/or white paper with a CD or DVD containing the actual and predicted sector capacities, and the corresponding traffic/weather scenarios. b. A conference and/or white paper with a CD or DVD containing the actual and predicted peak traffic demand data in fifteen-minute intervals over a 2-hour planning horizon, and the corresponding traffic/weather scenarios.	Original Current Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.3.4.05	Critical	Assess Representative System-wide TFM Models	10	4	The output of this effort is a suite of advanced TFM tools integrated into a simulation test bed.	Conference or journal publication describing the results of the system-wide traffic flow management experiments conducted in support of this milestone.	Original Current Completed
AS.3.4.06		Simulation Assessment of Advanced TFM Concepts			The output of this effort will be a system-level simulation assessment of the feasibility and benefits of implementing advanced TFM techniques.		Original Cancelled
AS.3.5.01	APG	Flight Test Evaluation of an Airborne Situation Awareness-based Application	7		Metrics that will be obtained in these flight trials include fuel savings compared to normal operations, system effectiveness in a flight environment, and operational acceptance.		Completed Original
AS.3.5.02		Field Evaluation of Trajectory Analysis Technology with Aircraft CNS Technology for Time-based Metering	7		Trajectory accuracy, fuel savings, noise footprint, workload, emissions		Original Completed
AS.3.5.03	Critical APG	Trajectory Analysis Technology for Automated Separation Assurance	8		Trajectory efficiency comparable to or better than today‘s operations. Near zero losses of separation. Integrated and coordinated functionality for strategic and tactical resolutions. Integrated trajectory analysis for aircraft with mix of equipage. Trajectory analysis for limited failure modes. Results based on laboratory analysis of actual Center traffic data in en route and transition airspace. Metrics analyzed as a function of traffic density and complexity.		Original Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.3.5.04	PART APG	Service-provider-based Automated Separation Assurance Simulation	8		Objective experimental data to quantify human workload, safety, and trajectory efficiency as a function of human/machine operating concept during nominal and failure modes in en route & transition airspace. General consistency with laboratory derived metrics (e.g., AS.3.5.03) and understanding of inconsistencies. Subject matter expert feedback (FAA, airlines, controllers, pilots) on operating concepts.		Original Completed
AS.3.5.05	PART IBPD APG	Auto SA Performance: Time-based Constraints	9	3	SA performance measures for efficiency and safety.	At least one technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	Original Completed
AS.3.5.06	PART IBPD APG	Auto SA HITL: 4D with Common Definitions	10	4	SA performance measures for efficiency, safety & capacity; human workload measures; subjective data.	At least one technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	Original Current Completed
AS.3.5.08	PART	Safety Assurance via Light-weight Formal Methods and Simulation			Methods and scenarios developed and tested with SA technology and operating concepts that probe the possible safety envelope. System safety defined under wide range of scenarios and conditions.		Original Cancelled Realignment Merged

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.3.5.10		Development of ASAS Applications in Procedural Airspace	9	4	Work complete in FY08.	Published paper or NASA TM on process to develop airborne-based separation procedures, and a published paper on results from batch study of ITP.	Realignment Completed
AS.3.5.11		Mixed Operations Concepts Formulated	10	4	Number of concepts formulated.	Concepts documented and reviewed by non-advocate board.	Realignment Current Completed
AS.3.5.14		Parametric RCNS	9	4	RCNS capability as function of capacity, throughput, efficiency, safety, predictability	At least one technical manuscript written and submitted for publication.	Realignment Completed
AS.3.5.15		HITL RCNS	10	3	Capacity, throughput, efficiency, safety, predictability	Technical manuscript written and submitted for publication.	Realignment Cancelled
AS.3.5.17		3D-PAM/EDA Simulations	10	4			Current Completed
AS.3.6.01		ASDO Initial Concept Definition	7		n/a	Internal report minimum, conference paper preferred.	Completed Original
AS.3.6.02	Critical	Refine Algorithms and Procedures for Merging and Spacing Operations to a Single Runway.	9	4	- Spacing variation at threshold of less than 10 seconds under normal conditions; - Off-nominal events do not disrupt overall flow.	Publication (or acceptance for publication) of NASA TM or at a technical conference.	Original Completed
AS.3.7.02	Critical	Develop Fast-time System-level Simulation of NGATS Technologies			The system-level simulation includes models of ASDO, SA, TFM, and DAC technologies.		Original Cancelled

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.3.7.04		Develop Prognostic Safety Assessment Methods for Systems and Operations			Independent peer review research results with ARMD AvSP and two external technical associations, including JPDO. System safety assessment methods to cover 85% of 2008 baseline safety case parameters. Operations safety assessment methods to provide quantitative methods for runway incursions, pilot/controller workload, taxi time over active runways, and unacceptable wake encounters. Prognostic safety assessment method recognized by two regulator bodies as providing credible assessments.		Original Cancelled
AS.3.7.06		Initial Common Definitions	9	4	Completeness of common definitions set, with verified applicability/ traceability to other NextGen Airspace RFAs, and JPDO Goals/Objectives, and Metrics. Broad and appropriate use by NextGen Airspace Program RFAs in their experiments, allowing apples-to-apples comparison with alternative concept approaches.	Published paper documenting the common metrics, demand sets and assumptions.	Completed
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))	8		Trajectory modeling consistency for various concepts	Lit search for AIDL and experimental plan for interoperability, panel chair for REACT workshop.	Original Completed
AS.2.1.03		Develop Vertical and Horizontal-profile Algorithms to Model Complex Combinations of Trajectory Constraints (Stemming from NGATS 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.	8		Trajectory accuracy parameters	4D FMS demo, GenAlt work checked into CTAS baseline and used by default	Completed Original

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.2.1.04		Survey and Advance Algorithms for Predicting and Describing Propagation of Trajectory Uncertainty	8		Algorithms account for effects of initial condition errors, aircraft dynamic model errors, and environmental variables.	Contractor report on uncertainty estimation toolbox	Original Completed
AS.2.1.05		Constraint Management Methods	10	4	Trajectory prediction accuracy in 4 dimensions.	Software deliverables - 4D FMS - integrate constraint relaxation into a simulation, constraint relaxation for CTAS checked into baseline.	Original Completed
AS.2.1.06		Complex Combinations of Constraints	9	4	Trajectory prediction accuracy in 4 dimensions.	Software deliverables - (4DFMS) multiple RTA capability, enhanced gen alt capabilities (constraint relaxation).	Original Completed
AS.2.1.08		Trajectory Uncertainty Modeling for EDA	9	4	Predicted meet-time distribution statistics at the meter point, predicted trajectory error distributions along the descent path.	Model the weight, winds, and performance errors for the three look-ahead times. In CTAS, calculate the meet-time and path performance errors based on the weight, wind, and performance error models.	Realignment Completed
AS.2.2.01		Produce a Comprehensive List of Performance Attributes Corresponding to the List of Candidate NGATS Operational Concepts	7		Operational performance attributes such as capacity, throughput, delays, predictability, flexibility, user preference, safety, workload, efficiency		Original Completed
AS.2.2.02		Working with Industry and the JPDO Shared Situation Awareness IPT, Produce a Set of Parametric Performance Models of CNS Systems	7		Communication, navigation, and surveillance characteristics and operational parameters (e.g., delays, response time, navigation precision, bandwidth)		Original Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.2.2.03		Group the Performance Attributes Under RNP, RCP, RSP, or an Advanced Performance Measure	8		Grouping of performance attributes		Original Completed
AS.2.2.04		CNS Performance Models are integrated into simulation systems and their performance is verified by actual operational data, where available.			CNS Performance (accuracy, reliability)		Original Realignment Merged
AS.2.3.01		Candidate Airspace Allocation Algorithms Proposed.			Number of candidate algorithms proposed		Original Cancelled Realignment
AS.2.3.02		Candidate Airspace Allocation Algorithms Validated			Number of candidate algorithms assessed, number of candidate algorithms validated		Original Cancelled Realignment
AS.2.3.03		Adaptable Airspace Algorithms	9	4	Number of algorithms developed.	Publication, white paper, or report.	Realignment Completed
AS.2.3.04		Airspace Redesign Benefit Analyses	9	4	Percent delay recovered over current sector design, number of sectors, workload and capacity variance, corridor utilization.	Publication, white paper, or report.	Realignment Completed
AS.2.3.05		Adaptable Airspace Benefit Analyses	10	4	% delay recovered over current sector design, complexity and capacity variance, degree of airspace change, corridor utilization.	Publication, white paper, or report.	Realignment Current Completed
AS.2.3.06		Define Flow Corridors Procedures	10	4	Number of procedures defined.	Publication, white paper, or report.	Realignment Current Completed
AS.2.4.01		Develop Oceanic Traffic Flow Optimization Concepts	8		Efficiency, throughput, delays, predictability		Original Completed
AS.2.4.02		An Improved Metric for Airspace Complexity is Defined	9	4	Statistical correlation between metric and airspace complexity.	Conference or white paper describing an improved metric for airspace complexity.	Original Completed
AS.2.4.03		Assess System-wide Performance of Oceanic Traffic Flow Optimization Concepts			Efficiency, throughput, delays, predictability		Original Cancelled

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.2.4.04		Update and Refine Airspace Evaluator Requirements for the Airspace Functions of the Evaluator			Identify interface control requirements for 85% of predictive throughput functionality to FY10 L4 "initial Airportal Evaluator". Airportal Evaluator concept functionalities to demonstrate 20% improvement in strategic decision optimization vs. capacity and throughput at 4 major airports over a 30 day period. Validate surface optimization requirements using 2010 OEP capacity and 3X forecast domain in fast-time simulation.		Original Cancelled
AS.2.5.01	PART	Strategic Automated Resolution and Trajectory Change Technology	7		95% of traffic conflicts are detected and resolved prior to the 3-5 min to loss of separation point with overall resolution delays and near-miss separation characteristics that are comparable or better than that of today's operations while operating under a significant increase in traffic density (e.g., 2-3x) and in the presence of uncertainty and under a variety of traffic conditions.		Original Completed
AS.2.5.02		Initial Operating Concept Options Description for Service-provider-based SA Approach	7		Description of a range of operating concepts (2 or 3) that will be evaluated in human-in-the-loop simulations. Operating concept descriptions include required technology, primary operator (controller/pilot) tasks, general user interface characteristics, examples of relevant operational traffic scenarios during nominal and failure modes.		Original Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.2.5.03		Initial Service-provider-based Automated Separation Assurance Simulation	7		Provides opportunity for researchers and stakeholders (e.g., FAA, airlines, controllers, pilots) to gain initial insight and provide initial feedback by viewing operating concept with humans in the loop. Initial objective analysis of operating concept during nominal and failure recovery operations. Initial evaluation of methods for gathering and analyzing experimental data, including metrics collected in laboratory analysis, during human in the loop simulations.		Original Completed
AS.2.5.04		Tactical Automated Safety Assurance Trajectories	8		Tactical detection and resolution logic computes safe tactical trajectories and thereby prevents a loss of separation for the majority of those traffic conflicts (~95% of the 5% not solved strategically) that were not resolved by strategic automated resolution technology and thereby prevent loss of separation while operating under a significant increase in traffic density and in the presence of uncertainty and under a variety of traffic conditions.		Original Completed
AS.2.5.05		Technology for Determining Weather Impacts on Tactical Airspace Operations	8		More useful/accurate characterization of weather impacts, ability to reduce lost usable airspace by 50% in some areas/conditions compared to today's operations.		Original Completed
AS.2.5.06		Dynamic Weather Technology	10	4	Fidelity of the convective weather representation.	Test report(s) written that document the V&V results for the convective weather representation capability in the relevant test bed(s).	Original Realignment Current Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.2.5.07		Analysis of Aircraft CNS Performance as it Relates to Separation Assurance Technology	9	4	Communications delays, negotiation delays, workload.	At least one technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	Original Completed
AS.2.5.08		Auto SA Performance: Complexity Constraints	10	4	SA performance measures for efficiency, safety, and complexity.	At least one technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	Original Realignment Current Completed
AS.2.5.09		Human Workload, Performance, and Situation Awareness Analysis of Higher Levels of Automation for Service-provider-based Separation Assurance			Workload, performance (response time and error), and situation awareness.		Original Cancelled
AS.2.5.14		Integration of CNS Performance Models into Simulation Test Beds	9	3	TBD	Technical manuscript written and submitted for publication (may be NASA internal).	Realignment Original Completed
AS.2.6.01		Flight Validation of Low Noise Guidance (LNG)	7		Ground noise measurements, conformance to guidance, fuel burn.		Original Cancelled
AS.2.6.02		Support for Initial Algorithm, Procedures and Information Requirements for Merging and Spacing Technology	7		Spacing variation at threshold of less than 10 seconds under normal conditions; off-nominal events do not disrupt overall flow.	Publication (or acceptance for publication) of NASA TM or at a technical conference	Original Completed
AS.2.6.03		Initial Sequencing and Deconfliction Algorithm	8		Throughput/capacity at major airports and regional/reliever airports, noise and emissions impacts, fuel use.	Internal report minimum, conference paper preferred.	Original Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.2.6.04		Develop Method for Airborne Maneuvering Within Established Limits to Make Gross Corrections to Inter-aircraft Spacing					Original Cancelled Realignment
AS.2.6.05		Information and Decision Support Requirements for Terminal Area Operations.	9	4	Definition of information content, accuracy, and frequency to enable development of Metroplex scheduling tool that meets arrival, departure, and surface operations needs, as well as complies with metroplex airspace constraints.	Publication (or acceptance for publication) at a technical conference.	Original Completed
AS.2.6.06J		Definition of Data Exchange Requirements for Airspace and Airportal Resource Scheduling Optimization	10	3	Degree to which interface definition can support Airspace and Airportal scheduler development.	NASA-TM documenting common interface definition for Airspace and Airportal schedulers	Original Realignment Cancelled
AS.2.6.09		Concept of Use for Terminal Tactical Conflict Prediction and Resolution Functions	10	4	Achieve concurrence from Project researchers and SME's that all fundamental requirements are present.	Publication (or acceptance for publication) at a technical conference.	Realignment Current Completed
AS.2.6.10		Fast-Time Simulation and Shadow Assessment of Terminal Tactical Conflict Prediction & Resolution Algorithm	10	3	Achieve false alert rate less than 10% and missed alert rate less than 5% for dense terminal airspace.	Publication at a technical conference minimum, journal preferred	Realignment Current Completed
AS.2.6.13		Initial Scheduling Capability for Static RNAV/RNP Operations using Efficient Descents in Dense Terminal Airspace	10	2	For major airports, reduce flight time during descent by 1 minute and enable 75% of arrivals to execute user-preferred descent profile.	Publication (or acceptance for publication) at a technical conference.	Realignment Current Completed
AS.2.7.10		Human Factors Assessment I	9	4	Prioritized list of NextGen human performance issues, vetted by relevant human performance research community (e.g. composite University, NASA, FAA) for thoroughness (breadth & depth).	Publication of research results in relevant conference or journal.	Realignment Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.2.7.11		Define Candidate Updates to FAA's Multi-Sector Planner (MSP) Midterm Concept of Operations (ConOps.)	9	4	Vetted (with DAC, SA, ASDO, & TFM) list of candidate MSP Midterm ConOps updates.	Published white paper describing possible extensions to MSP midterm ConOps for 2018, specifically calling out significant areas of overlap or potential integration with SA, TFM, DAC and/or ASDO research.	Realignment Completed
AP.1.C.02		Assess Sensitivity and Accuracy of Current Real-tie Wake Vortex Models and Improve Performance as Needed	10	4	The results define the key parameters needed for assessment of wake prediction and provides quantification of wake motion and decay uncertainty from deterministic wake models in terms of these parameters. Compare model results against LES results and available field data to estimate accuracy of predictions for various aircraft types and realistic ambient conditions. Estimate the range of ambient conditions where vertical shear effects may be operationally significant. Target values are not appropriate for this milestone; the intent is to quantify the state of the art in terms relevant to application of wake knowledge to alternate operational procedures.	Referenceable publication documenting enhancements to fast-time model	Current Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AP.2.C.04		Initial Airport Runway Configuration Management (RCM) and Combined Arrival/Departure Runway Scheduling (CADRS) Algorithms for a Single Runway at a Single Airport	10	3	Metrics include airport throughput and/or total aircraft delays with a fixed demand during steady state weather conditions and during wind shifts requiring runway configuration changes. Benefit is validated by comparing throughput to that produced by subject matter experts (SMEs) in the same scenarios and by comparison to the estimated theoretical maximum throughput values (considering no uncertainties or unused slots). The target for the initial algorithm is performance at least equal to an experienced SME.	Referenceable publication, preferably a NASA TM or TP, documenting the algorithms, evaluation scenarios, and stand-alone performance	Current Completed
AP.2.C.06		Wake Vortex Predictor that Provides Probabilistic Estimates of Wake Location	10	4	Defined confidence intervals (confidence levels for spatial accuracy of prediction as a function of wake age, wind values, generating-aircraft weight range, and ground proximity). Confidence bounds validated via separate data sets, new data sets that may become available from FAA field tests. Validation extent is contingent upon availability of new data sets.	NWRA status report and preliminary PDFs for wake vortex predictor that provides probabilistic estimates of wake location.	Current Completed
AP.3.C.05J		Initial Evaluation of Integrated Systems for Optimizing Automated Surface Operations and Arrival/Departure Operations	10	4	Metrics include average taxi delay reduction and airport throughput increase under a range of traffic density with first generation integrated operations. Results to be used to determine issues associated with surface/runway integration and to feed system studies to define future research.		Cancelled

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AP.3.S.02		Integrate and Evaluate Surface Traffic Planning Algorithms	10	4	Via simulation to show the ability to manage up to 2x traffic demand scenarios with taxi delays similar to the baseline (1x throughput without optimization). Results of this milestone will be used to determine the utility of this optimization approach. Metrics include average taxi delay reduction, throughput increase, environmental impacts, and fuel efficiency under increased Airportal traffic density. The performance improvement will be assessed by subject matter experts presented with the same current and future traffic-demand scenarios. Results are used to feed benefits analysis and trade studies to assess potential utility of taxi route optimization.	Conference paper reporting the results of modeling and analysis of NextGen surface operations.	Current Completed
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 NGATS Automation Systems	8	4	Current SOA reported and documented.	draft documents detailing capabilities for existing tools, 5 docs delivered	Completed Original
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 NGATS-Relevant Trajectory Prediction for the Evaluator and Related Automation	8	4	Trajectory accuracy parameters	Presentation on developing requirements for new tools	Original Completed
AS.1.1.03		Develop Algorithms for Measuring the Difference Between 4D Trajectories	7	4	Algorithms developed with sufficient sensitivity to identify differences between actual vs. predicted trajectories, FMS vs. ground-tool trajectory predictions, and U.S. vs. European trajectory specifications.		Completed Original

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.1.1.04		Identify and Quantify a Complete Set of Constraints and Objective Functions Typically Applied to Trajectories to Support ATM Functions	8	4	Constraints and objective functions documented from DAC, TFM, SA, and ASDO. Quantification includes typical values, bounds, or conformance precision, as appropriate to the ATM function.	Paper on Abstraction techniques	Completed Original
AS.1.1.05		Identify and Quantify Sources of Uncertainty for Trajectory Prediction	7		Characterization of trajectory prediction uncertainty includes sensitivities to wind prediction uncertainty, aircraft aero/engine performance variables, auto-flight mode, RNP, crew procedures, and flight segment type.		Original Completed
AS.1.1.06		Develop Data Mining Techniques for Identifying Trends in Trajectory Intent Error	8		Techniques validated to accurately identify trends in at least 80% of known trajectory intent errors from a current-day validation data set.	Paper on data mining of intent errors GN&C 2008	Completed Original
AS.1.2.01		Identify Suitable Techniques for Modeling RTSP Performance Characteristics.	9	1	The metrics include comprehensiveness and peer review acceptance.		Original Completed
AS.1.2.02		Synthesis of Human Factors and Operational Literature	8		The metrics are the comprehensiveness of human performance characteristics.		Cancelled Original
AS.1.2.03		Extensions of Analytical and Statistical Techniques for Modeling RTSP Performance Characteristics			The metrics are the techniques explored are of sufficient maturity to construct parametric models for RTSP for use in modeling and simulation.		Original Cancelled Realignment Merged
AS.1.2.04	Critical	Identify Grouping Techniques that will Classify/Represent the Multi-dimensional Nature of RTSP Performance Characteristics. Identify Decision Support and Information Presentation Techniques Applicable to Grouping Techniques.	10		The metrics are the grouping characteristics (robustness, consistency, sensitivity, and face validity)		Original Cancelled
AS.1.3.01		The State of the Art is Surveyed and Documented	7		Breadth and depth of survey.		Completed Original

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.1.3.02		The Elements of Airspace Structure in the NAS are Inventoried, and "Best Practices" in Airspace Design are Documented. Adapt for NGATS.	7		Breadth and depth of inventory.		Original Completed
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.			Number and type of airspace units within the NAS		Original Cancelled Realignment
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.	8		This research should improve our ability to estimate aggregate delay based on predicted weather and expected traffic to within 10,000 minutes based on 2006 traffic levels.		Completed Original
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	8		The aggregate models should demonstrate a 10 times reduction in the size of the models used for analysis.		Completed Original
AS.1.4.03		Characterize Current and Future ATM Systems by Adapting Concepts from Network and Graph Theory	8		The success of this milestone will be measured by its ability to characterize the new ATM network with a higher level of varying demand than today.		Completed Original
AS.1.4.04		Expand the Concept of Traffic Complexity to Controller, Pilots and Varying Levels of Automation	8		The metric for this research is the increase in the ability to define traffic complexity from the current state of the art and expand it to pilots and varying levels of automation.		Original Merged

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
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	10	4	The probabilistic methods should demonstrate a 10% improvement in the aggregate system delay or other appropriate system measures over deterministic methods.	Conference or journal publication describing probabilistic or stochastic flow management algorithms, concepts, models for managing individual flights or flows of flights in the presence of system uncertainties.	Original Completed
AS.1.5.02		Methodology for Analysis of Tactical ATC and Airborne Collision Avoidance Interaction	8		Method developed and validated with actual air traffic data in the presence of uncertainties.		Original Completed
AS.1.5.03		Analytical Methods to Assess System Response to Failure Events	10	4	Method developed and validated with actual air traffic data in the presence of uncertainties.	At least one technical manuscript written and accepted for publication that meets the research objective as stated in the milestone description.	Original Current Completed
AS.1.5.04		Methods for Quantifying Safety Level of Human Operators in ATM System	8		Method developed and validated in simulation in the presence of uncertainties.		Original Cancelled
AS.1.5.06		Formal Proof of Separation Assurance for Oceanic Applications	7		Completeness		Original Completed
AS.1.5.07		Recommended Complexity Metric	8		Number of machine operations		Original Completed
AS.1.5.09		RCNS Parameter Definition	10	4	Suggested definitions for future CNS performance requirements.	Technical manuscript written and submitted for publication (may be NASA internal).	Realignment Current Completed

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.1.5.10		Extensions of Analytical and Statistical Techniques for Modeling RTSP Performance Characteristics	10	2	Techniques are sufficiently mature to construct parametric models for RTSP for use in modeling and simulation.	Technical manuscript written and submitted for publication.	Realignment Completed Current
AS.1.6.01		Characterize and Quantify the Uncertainty Impact of ASDO Procedures	8		n/a	Internal report minimum, conference paper preferred.	Completed Original
AS.1.6.02		Investigate Scheduling and Rationing Algorithms for Weather Impacted NAS Resources	10	4	Decrease weather induced delay by 30%.	Publication at a technical conference minimum, journal preferred.	Original Current Completed
AS.1.6.03		Develop Advanced FMS Guidance and Control Algorithms to Enable Late-term ASDO Operations	10	4	Reduce fuel usage during high density terminal operations by 5% while increasing the percentage of aircraft achieving stabilized approach criteria by 5%.	1) ATOL upgraded with eNAV capability by July 2009. (Complete). 2) NASA TM or technical conference publication by summer of 2010.	Original Current Completed
AS.1.6.04		Explore Innovative Guidance and Control Methods for the Super Density Terminal Environment			Review of guidance and control methods, their strengths and weaknesses		Cancelled Realignment Original
AS.1.6.05		TRACON Operational Error Analysis	9	4	Detect all provided operational errors at least 2 minutes ahead of time.	Publication (or acceptance for publication) at a technical conference.	Realignment Completed
AS.1.7.01	Critical	Develop initial system-level Con-Ops. Leverage JPDO NGATS Con-Ops, and Expand Development as Required, to Support Airspace Systems Program (Airspace & Airportal) Research, and Concept Development.	7		Completeness by containing JPDO (stakeholder) and technologist views on separation assurance, demand/capacity imbalance and airspace modifications.		Completed Original

B-1. Legacy Milestones – FY 2007 - FY2010

Milestone ID	Key Milestone	Title	Scheduled Completion FY	Q	Planned Metric	Exit Criteria	Status
AS.1.7.03	Critical	Develop Individual Agent-based Models of NextGen Technologies	8	4	These models shall include at least ASDO, TFM, SA, and DAC	Document agent-based model development (completed models and planned models). Publish available capabilities in relevant conference or journals	Original Completed
AS.1.7.04		Develop Interim System-level Concept of Operations to Accommodate 3x Demand Based on Results of Studies and Identified Gaps			Less than 50% change from initial version and stakeholder vetted.		Original Cancelled
AS.1.7.05		Develop Approach for System Validation and Certification Methodology			Results for AAC, ASAS, and TCAS algorithms.		Original Cancelled Merged

B-2. Current Milestones FY2011 – FY2015

Appendix B-2 contains current milestones for each RFA planned for FY2010 – FY2015. Project milestones are distinguished by level of research, according to the following criteria:

- Level 1 milestones focus on foundational physics and modeling and include research in automation design, human factors, the use of applied mathematics for system optimization and design.
- Level 2 milestones focus on discipline such as safety analysis and recovery methods, trajectory design and conformance, and multi-aircraft flow and airspace optimization.
- Level 3 milestones consider multi-discipline capabilities with a key focus on adaptive air and ground automation concepts and technologies, airspace simulation and modeling, and systems analysis and integration.
- Level 4 milestones address system-design with an emphasis on integrated solutions for a safe, efficient, and high-capacity national airspace system.

Table 2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.4.3.02		Airspace Class Integration	Simulate the interactions between mature airspace classes and analyze system wide effects.	% delay recovered over current sector design, corridor utilization.	Publication, white paper or report	14	4	AS.3.3.07 AS.3.3.09 AS.3.3.10	
AS.4.3.03		Incorporate System Level Feedback	Refine integrted DAC concept by incorporating feedback from system level studies with DAC. Simulate the interactions between mature airspace classes and analyze system wide effects.	% delay recovered over current sector design, corridor utilization.	Publication, white paper or report.	15	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.4.4.01	Critical	Develop and Test Early Integrated Traffic Flow Management (TFM) Concepts for Advanced Traffic Flow Management to Accommodate User Preferences, Reduce Delays and Increase Efficiency Under All-weather Conditions	The purpose of this milestone is to develop and validate advanced algorithms and approaches to accommodate user preferences, reduce delays, and increase efficiency under nominal and off-nominal conditions. The TFM algorithms will include accommodation of 3x traffic demand under a variety of normal and severe weather conditions. The TFM algorithms will include both national and regional aspects to cover the appropriate planning horizons. The algorithms will address the appropriate balance between national and regional flow management for a set of traffic/weather scenarios, and will utilize a combination of deterministic and stochastic methods to increase the predictability of traffic, weather, and their interactions. The validation will include both objective and subjective data. Research will also be conducted to investigate the trade-offs service provider and aircraft operator control authority, e.g., gate-to-gate 4D contracts for "conventionally" equipped aircraft as well as point-type flow restrictions for 4D-ASAS equipped aircraft. Completion of this milestone will necessitate the designing and performing of numerical simulation studies, as well as higher fidelity HITL experiments to assess roles, responsibilities, procedures, displays, information needs, as well as accuracy and usefulness of algorithms.	The specific metrics for this milestone include delays, throughput, fuel efficiency, flight duration, complexity distribution, workload, and user preference accommodation. The actual savings will be dependent on the concept of operations.	Conference or journal publication describing key algorithms and models associated with the TFM Evaluator and the results of fast-time simulation experiments.	11	4	AS.3.4.01 AS.3.4.02 AS.3.4.03 AS.3.4.04 AS.3.4.05 AS.3.4.06	AS.2.4.05 AS.3.4.07 AS.3.4.09

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.4.5.01	Critical	Auto SA Simulation: Homogeneous Airspace Under Off-nominal Conditions	Simulating with humans in the loop, the allocation of separation responsibility between humans and automation is separately analyzed for user- and ANSP-based approaches. Assumptions, scenarios, uncertainty and metrics are common such that the experimental results generated by different concepts can be directly compared. Scenarios to include off-nominal conditions such as adverse weather and failure modes.	SA performance measures for efficiency, safety & capacity; human workload & situation awareness measures; subjective data.	Technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	13	2	AS.3.1.03 AS.3.3.03 AS.3.4.03 AS.3.4.04 AS.3.4.05 AS.3.5.11 AS.3.5.12 AS.3.6.04 AS.3.7.01	AS.4.5.02
AS.4.5.02		Auto SA Simulation: Mixed Operations Airspace Under Off-nominal Conditions	Conduct simulation of automated SA in mixed ops airspace. Focus on controller/pilot /automation roles & responsibilities when SA responsibility is exchanged and when responsibility is not exclusively allocated to one domain or the other (air nor ground). Assumptions, scenarios, uncertainty and metrics are common such that the experimental results generated by different concepts can be directly compared. Scenarios to include off-nominal conditions such as adverse weather and failure modes.	SA performance measures for efficiency, safety & capacity; human workload & situation awareness measures; subjective data.	Technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	14	2	AS.1.7.04 AS.3.5.11 AS.3.5.13 AS.4.5.01	AS.4.5.03
AS.4.5.03		Final Report on Functional Allocation	In a document summarizing the combined findings of the experimental research conducted in the Separation Assurance research focus area, cite and discuss the strengths and weaknesses of the range of concepts and technologies explored. Include discussion of prospects of each approach for safety analysis and certification.	none	Technical manuscript written and submitted for publication.	14	4	AS.4.5.02	NA

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.4.6.01		Final Concept of Operations for Automated, Mixed Operations in Metroplex Environment	Final compilation of integrated terminal area and airport operational concepts for high-density, metroplex environments, based on user feedback and all research conducted in SDO. Analysis discusses trade spaces explored, operational impact of different concept options, requirements, and recommendations. Contains detailed performance assessment and justification for specific technologies needed to achieve N-times current capacity.	- For major airports, increase peak aircraft throughput by 15%, decrease mean delay by 25% and decrease mean flight time during descent by 2 minutes. - For metroplex, increase peak operations by 100%, decrease mean flight time during descent by 3 minutes and ensure full utilization of available runway resources.	Technical Publication documenting refined concept of operations. Conference publication minimum, journal publication preferred.	15	3	AS.3.6.03 AS.3.6.05 AS.3.6.06 AS.3.6.07 AS.3.6.08	NA
AS.3.3.06		Validate Flow Corridors Feasibility	Validate the feasibility of proposed flow corridor procedures in HITL experiments. Estimate safe capacity thresholds for each procedure.	Workload measures for each procedure.	Publication, white paper or report.	11	4	AS.2.3.06 AS.3.3.04 AS.3.3.05	AS.2.3.08 AS.3.3.08
AS.3.3.07		Interactions Between Airspace Classes	Research how multiple coexisting classes of airspace interact with one another. For example, creating a flow corridor will affect the optimal configuration of high altitude airspace surrounding it. Changes in low altitude airspace in response to metroplex configuration changes will affect enroute airspace. What is the right balance of different airspace classes given the demand traffic and how do they gracefully transition between one another?	Number of algorithms, procedures developed.	Publication, white paper or report.	12	4	AS.2.3.05 AS.3.3.05	AS.2.3.08 AS.3.3.08 AS.3.3.09 AS.4.3.02

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.3.3.08		Dynamic Terminal Airspace II	Study the interaction between DAC algorithms and ASDO algorithms. Develop a method for DAC and terminal airspace integration.	Number of integration methods developed, capacity, efficiency, and robustness.	Publication, white paper or report	12	4	AS.2.3.07 AS.3.3.06 AS.3.3.07	AS.3.3.09 AS.3.3.10
AS.3.3.09		Refine DAC Concepts	Refine adaptable airspace allocation based on DAC/ASDO and DAC/TFM integration considerations.	% delay recovered over current sector design	Publication, white paper or report	13	4	AS.3.3.07 AS.3.3.08	AS.4.3.02
AS.3.3.10		Refine Flow Corridor Procedures	Refine flow corridor procedures based on DAC/ASDO and DAC/TFM integration considerations.	% delay recovered over current sector design, corridor utilization.	Publication, white paper or report	13	4	AS.2.3.08 AS.3.3.08	AS.4.3.02
AS.3.3.11		Operator Roles and Responsibilities	Research the roles and responsibilities of the airspace operator in various classes of airspace	Airspace capacity, description of operator roles and responsibilities.	Publication, white paper or report.	11	4		
AS.3.4.07		Initial Collaborative Experiments	Develop and evaluate initial airline and service provider models in fast time simulation experiments of collaborative flight and flow evaluation and resolution capabilities. The goal of the fast time simulation experiments will be to establish the initial roles and responsibilities of the flight operators and ANSP in identifying airspace constraints, performing flight/flow impact assessments, replanning individual flights and flows, and implementing flight path modifications will be examined.	Demonstrate a 5% improvement in the ability to accommodate user preferences with the algorithms and models developed in support of this milestone over more traditional traffic flow management approaches that neglect to account for user preferences.	Conference or journal publication describing the results of the initial collaborative traffic flow management experiments	12	4	AS.3.4.03 AS.4.4.01	AS.3.4.08 AS.3.4.10 AS.3.5.12

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.3.4.08		Refined Collaborative Experiments	Develop and test refined airline and service provider models in fast time and initial human-in-the-loop simulations of collaborative flight and flow evaluation and resolution capabilities. The goal of these experiments is to establish refined roles and responsibilities of the flight operators and ANSP in identifying airspace constraints, performing flight/flow impact assessments, replanning individual flights and flows, and implementing flight path modifications will be refined.	Demonstrate a 10% improvement in the ability to accommodate user preferences with the algorithms and models developed in support of this milestone over more traditional traffic flow management approaches that neglect to account for user preferences.	Conference or journal publication describing the results of the refined collaborative traffic flow management experiments	14	4	AS.3.4.07	None
AS.3.4.09		Baseline Flow Planning Under Uncertainty	Enhance the baseline TFM Evaluator with probabilistic and stochastic methods for formulating alternative approaches to managing individual flights and traffic flows that demonstrate the automated integration of weather, demand, and capacity estimates into the decision making process.	Demonstrate a 5% reduction in total delays when managing flights in the presence of system uncertainties over current TFM practices that rely on an uncoordinated collection of open-loop deterministic controls, such as ground delay programs, miles-in-trail restrictions, and playbook reroutes	Conference or journal publication describing the enhancements to the baseline Evaluator and the results of the fast-time simulations conducted in support of this milestone.	12	4	AS.1.4.05 AS.1.4.06 AS.4.4.01	AS.3.4.10

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.3.4.10		Refined Flow Planning Under Uncertainty	Building on the baseline TFM Evaluator system, develop an initial agile, iterative approach for managing traffic flows that accounts for flight operator preferences while leveraging state-of-the-art weather translation models in the 0-2 hour look-ahead time horizon.	Demonstrate an 8% reduction in total delays or a 5% improvement in the ability to accommodate user preferences when managing flights in the presence of system uncertainties over current TFM practices that rely on an uncoordinated collection of open-loop deterministic controls, such as ground delay programs, miles-in-trail restrictions, and playbook reroutes.	Conference or journal publication describing the agile, iterative approaches to managing traffic flows.	13	3	AS.2.4.05 AS.3.4.07 AS.3.4.09	AS.2.4.06 AS.3.4.11

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.3.4.11		Agile Decision Making with Uncertainty	Develop and test an integrated approach to flow management that explicitly accounts for probabilistic information (e.g., weather, congestion), management of uncertainty, what-if analysis, and integrated incremental resolutions to support an alternative selection of how to achieve agile and effective incremental traffic flow management decisions.	Demonstrate a 10% reduction in total delays or an 8% improvement in the ability to accommodate user preferences when managing flights in the presence of system uncertainties over current TFM practices that rely on an uncoordinated collection of open-loop deterministic controls, such as ground delay programs, miles-in-trail restrictions, and playbook reroutes.	Conference or journal publication describing the key models, algorithms, and concepts that comprise the integrated, agile decision making system.	14	4	AS.3.4.10	None
AS.3.4.12		Environmental Impact Assessment of Traffic Flow Planning	Develop and test a “toolkit” for assessing the environmental impact of representative traffic flow management concepts (e.g., weather avoidance routing, national- and regional-level flight scheduling, etc.). This toolkit should help guide the development of refined, environmentally aware traffic flow management models that seek to mitigate predicted imbalances in air traffic demand and capacity while reducing emissions, such as carbon dioxide and water vapor.	The environmental toolkit should demonstrate an ability to compute emissions of carbon dioxide, water vapor, and nitrogen oxide and also fuel flow for a representative traffic flow concept.	Conference or journal publication describing the key components of the environmental toolkit and results demonstrating the use of the toolkit on a representative traffic flow management concept.	15	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.3.4.13		Risk Management Based Flow Management	Develop risk management based approaches for efficiently planning and recovering from unforeseen changes in system capacity or demand. Such changes could result, for example, from inaccurate weather forecasts, "pop-up" flights, or equipment outages. Candidate techniques may include the development of pre-coordinated airborne holding reservoirs, alternative landing airports, etc.	Demonstrate an improvement in the ability to manage the risks associated with flow planning under uncertainty over the current state-of-the-art.	Conference or journal publication describing the key models, algorithms and concepts developed for managing traffic flow management risks in the presence of system uncertainties.	15	4		
AS.3.5.07	Critical	Integrated SA Capabilities: 4D with Dynamic Weather & Complexity Constraints	Performance of candidate user-based and ANSP-based algorithms is evaluated, where conflict resolution is subject to sequencing and spacing constraints, hazardous weather constraints, and where complexity measures, if possible, are considered in the conflict-resolution cost function. The research objective is to determine the extent to which these capabilities can be integrated into our candidate conflict-resolution algorithms, and to determine the extent to which the resulting integrated algorithms can perform subject to all of these constraints.	SA performance measures for efficiency and safety.	At least one technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	11	2	AS.2.5.08 AS.2.5.13 AS.3.5.06	AS.3.5.13
AS.3.5.12		Auto SA Simulation: Homogeneous Airspace Under Nominal Conditions	Simulating with humans in the loop, the allocation of separation responsibility between humans and automation is separately analyzed for user- and ANSP-based approaches. Assumptions, scenarios, uncertainty and metrics are common such that the experimental results generated by different algorithms can be directly compared.	SA performance measures for efficiency, safety & capacity; human workload & situation awareness measures; subjective data.	Technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	11	3	AS.3.4.07 AS.3.5.09 AS.3.5.10 AS.3.5.11 AS.3.5.15	AS.3.5.13 AS.4.5.01

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.3.5.13		Auto SA simulation: Mixed Operations Airspace Under Nominal Conditions	Conduct simulation of automated SA in mixed ops airspace. Focus on controller/pilot/automation roles & responsibilities when SA responsibility is exchanged between them and when separation responsibility in an airspace is not exclusively allocated to one domain nor the other (air nor ground). Assumptions, scenarios, uncertainty and metrics are common such that the experimental results generated by different concepts can be directly compared.	SA performance measures for efficiency, safety & capacity; human workload & situation awareness measures; subjective data.	Technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	12	2	AS.1.7.04 AS.2.5.11 AS.3.5.11 AS.3.5.13	AS.4.5.02
AS.3.5.16		Develop Approach for System Validation/Certification of SA Systems and Concepts	Both traditional and advanced methods for system validation and certification will be required to enable eventual implementation of NextGen technologies. While NASA will not be responsible for system certification, NASA will maintain cognizance with current and evolving certification standards and work with our FAA partners to ensure that NextGen concepts are designed with certification in mind. The research objective is to identify and/or develop the methodologies that could support verification, validation, and certification of automated SA systems and concepts.	Stakeholder vetting and peer review	Technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	13	3	AS.1.5.05 AS.2.5.12	NA

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.3.5.18		Dynamic Flow Control for Airborne Trajectory Management with Self Separation	Airborne trajectory management with self-separation enables aircraft to manage its trajectory in en-route and transition airspace while complying with global flow control and demand constraints. Trajectory constraints include arrival time constraints, airspace access restrictions, and company trajectory requirements and guidance as well as transitioning to different modes of trajectory control upon arrival, such as airborne precision spacing. A capability to dynamically generate these trajectory constraints and provide them to the aircraft will permit of the interactions between airborne trajectory management with self-separation and anticipated ground-based functions.			15	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.3.5.19		Near-term Concept for Trajectory-based Operations with Datalink Simulations and Analysis	Simulation evaluations of a near-term concept for Trajectory-Based Operations with today's datalink capabilities and mixed equipage operations. Simulation includes laboratory analysis and human-in-the-loop simulations. Objective is to validate human/automation concept and airspace and service provide benefits for today's operations with currently available cockpit equipment.	Two human-in-the-loops simulations with controllers and pilots. Analysis that provides direct comparison with today's operations. Evaluation of mixed aircraft equipage operation including voice only, non-integrated datalink, and integrated FMS/datalink.	1) Research prototype real-time system with 4 of the following 5 capabilities running integrated in real time: fuel-efficient descent advisories, minimum-delay weather avoidance, wind-favorable routes, arrival manager for time based metering, tactical detection and resolution. 2) Three papers sumitted to conference or journal.	11	4		
AS.3.6.03		Evaluation of Single Airport Operations Using Medium-term Technologies.	Evaluate human-centric single airport using mid-term technologies (CDAs to CSPAs, RNAV/RNAP routing and FDMS) in mixed operations. Quantify benefits, such as throughput, delay and efficiency, using high fidelity simulations. Assess controller acceptability using HITL simulations. Determine restrictions, such as minimum equipage requirements, mixed equipage limits and demand management. Assess man/machine functional allocation with increasing technology.	For major airports, increase peak runway throughput by 5%, decrease mean flight time during descent by 1 minute, and attain 75% conformance to prescribed trajectories in nominal conditions.	Publication (or acceptance for publication) at a technical conference.	11	2	AS.2.6.03 AS.2.6.07 AS.3.6.01 AS.3.6.02	AS.3.6.05 AS.4.6.01

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.3.6.04		Concept of Operations and Requirements for Coordinated Operations at a Single Airport.	Airspace and Airportal Projects jointly develop definition of integrated operational concepts for descent from cruise through landing and taxi to gate, and for taxi from gate through takeoff and climb to cruise for both human-centric and automated single airport operations. Define requirements for management of airborne resources (buffers, dynamic routing and service levels) and negotiation for surface resources (airport configurations, runways, taxiways, ramps, and gates).	Results provide requirements for interfacing concepts, information exchange, and operational procedures developed within the Projects for culminating experiments to be conducted by ASDO, CADOM, SESO, and AMI.	Completion of requirements review headed by Airportal and Airspace Project Scientists, NASA-TM documenting concept of operations and requirements for integrated operations at a single airport.	11	3	AS.2.6.07 AS.2.6.13 AS.3.6.01 AS.3.6.02 AP.2.C03 AP.3.C.05 AP.3.S.02	AS.3.6.05 AS.3.6.06 AP.3.A.04 AP.3.A.13 AP.3.C.10 AP.3.C.11 AP.4.C.01 AP.4.A.01 AP.4.A.02
AS.3.6.05		Evaluate Single Airport Operations Using Late-term Technologies.	Evaluate automated single airport using late-term technologies (advanced scheduling capabilities and integrated operations). Quantify benefits, such as throughput, delay and efficiency, using high-fidelity simulations. Assess human roles and responsibilities using HITL simulations. Determine restrictions, such as minimum equipage requirements, mixed equipage limits and demand management. Assess ground/air functional allocation with increasing traffic load.	For major airports, increase peak airport throughput by 15%, decrease mean flight time during descent by 2 minutes, and attain 90% conformance to prescribed trajectories in nominal conditions.	Publication at a technical conference minimum, journal preferred.	12	4	AS.2.6.08 AS.2.6.14 AS.3.6.03	AS.3.6.08 AS.4.6.01
AS.3.6.06	Critical	Definition of Coordinated Arrival/Departure /Surface Operations for Metroplex	Develop definition of coordinated arrival/departure/surface operations for both human-centric and automated metroplex. Define requirements for coordination of resources shared by multiple airports. Coordinated resources can be used by multiple airports but not at the same time.	For metroplex, decrease flight time during descent by 2 minutes	Publication (or acceptance for publication) at a technical conference	12	2	AS.2.6.08 AS.2.6.14 AS.3.6.04	AS.3.6.07 AS.4.6.01

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.3.6.07		Evaluation of Metroplex Operations using Near-term Technologies	Evaluate human-centric metroplex using mid-term technologies (CDAs to CSPAs, RNAV/RNP routing, and FDMS). Quantify benefits, such as throughput, delay and airspace utilization using high fidelity simulations. Assess controller acceptability using HITL simulations. Determine restrictions, such as minimum equipage requirements, mixed equipage limits and demand management. Assess man/machine functional allocation with increasing technology.	For metroplex, increase peak operations by 50%, reduce flight time during descent by 2 minutes, and attain 75% conformance to prescribed trajectories in nominal conditions.	Publication (or acceptance for publication) at a technical conference	14	3	AS.2.6.14 AS.3.6.06	AS.3.6.08 AS.4.6.01
AS.3.6.08		Evaluation of Metroplex Operations using Late-term Technologies	Evaluate automated metroplex using late-term technologies (advanced scheduling capabilities and integrated arrival/departure/surface operations). Quantify benefits, such as throughput, delay and airspace utilization using high-fidelity simulations. Assess human roles and responsibilities using HITL simulations. Determine restrictions, such as minimum equipage requirements, mixed equipage limits and demand management. Assess ground/air functional allocation with increasing traffic load.	For metroplex, increase peak operations by 100%, reduce flight time during descent by 3 minutes and attain 90% conformance to prescribed trajectories in nominal conditions.	Publication at a technical conference minimum, journal preferred	15	2	AS.2.6.12 AS.3.6.05 AS.3.6.07	AS.4.6.01

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.3.6.09		Evaluation of Management Procedures to a Single Airport with Dependent Parallel Runways	Evaluate flight crew procedures for Interval Management into a single airport using mid-term technologies (CDAs to CSPAs, RNAV/RNAP routing and FDMS) in mixed operations to multiple runways. Research issues, airport, scenarios, and schedule to be similar to AS.3.6.03. Quantify benefits, such as throughput, delay and efficiency in both batch and HITL simulations. Assess pilot acceptability and workload using HITL simulations. Assess man/machine functional allocation with increasing technology.	Improved precision of delivery time to a specified point (e.g., meter fix or runway threshold) or behind another aircraft, compared to current operations in busy terminal operations.	Publication of experiment results	12	4		
AS.3.6.10 (Jt.SAIE.IE T.3.02)	APG	Evaluation of Interval Management Procedures to a Single Airport with Delegated Separation	Evaluate flight crew procedures for Interval Management into a single airport using mid-term technologies in mixed operations to multiple runways, with responsibility for separation from the reference aircraft delegated to the flight crew (PO-ASAS 3). Research issues, airport, scenarios, and schedule to be similar to AS.3.6.03. Assess pilot acceptability and workload using HITL simulations. Assess man/machine functional allocation with increasing technology.	Improved precision of delivery time to a specified point (e.g., meter fix or runway threshold) or behind another aircraft, compared to current operations in busy terminal operations with no increase in separation violations.	Publication of Experiment Results	12	4		
AS.3.6.11	APG	Initial Evaluation of Terminal Tactical Conflict Prediction and Resolution Functions	Assess the air traffic controller and flight crew acceptability of the initial automated tactical conflict avoidance functionality in dense terminal airspace. Determine the acceptability of the initial avoidance function in terms of workload, situational awareness, and perceived safety using a mid-fidelity air traffic control and flight deck simulators.	Marginally acceptable ratings for workload and situational awareness. Achieve false alert rate less than 5% and missed alert rate less than 1% for dense terminal airspace.	Publication (or acceptance for publication) at a technical conference	11	4	AS.2.6.10	AS.2.6.12

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.3.6.12		Definition of Integrated Arrival/Departure /Surface Operations for Metroplex	Develop definition of integrated arrival/departure/surface operations for both human-centric and automated metroplex. Define requirements for integration of resources shared by multiple airports. Integrated resources can be used by multiple airport at the same time.		Publication at a technical conference	13	4		
AS.3.6.13		Initial Terminal Airspace Reconfiguration Techniques for Single Airport during Peak Traffic Periods	Develop procedures, route generation algorithms and decision-support tools needed to maintain seamless trajectory-based single airport operations during airport and runway configuration changes.		Publication at a technical conference	13	4		
AS.3.6.14		Evaluation of Single Airport Operations using Integrated Scheduling, Control and Tactical Conflict Prediction & Resolution	Evaluate automated single airport using fully integrated technologies (advanced scheduling capabilities, coordinated operations, automated tactical conflict prediction & resolution and advanced flight deck capabilities). Assess human roles and responsibilities using HITL simulations. Determine restrictions, such as minimum equipage requirements, mixed equipage limits and demand management. Assess ground/air functional allocation with increasing traffic load.		Publication of experiment results	14	2		
AS.3.6.15		Initial Terminal Airspace Reconfiguration Techniques for Metroplex during Peak Traffic Periods	Develop procedures, route generation algorithms and decision-support tools needed to maintain seamless trajectory-based Metroplex operations during airport and runway configuration changes.		Publication at a technical conference	15	2		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.3.6.16		Evaluation of Interval Management with Tactical Conflict Prediction & Resolution to a Single Airport or Metroplex	Evaluate flight crew procedures for Interval Management into a single airport or metroplex using mid-term technologies in mixed operations to multiple runways, with responsibility for separation to all aircraft delegated to the flight crew (PO-ASAS 4). Research issues, airport, scenarios, and schedule to be similar to AS.3.6.05, and leverage work from AS.2.6.12. Assess pilot acceptability and workload using HITL simulations. Assess man/machine functional allocation with increasing technology.		Publication of experiment results	14	2		
AS.2.3.07		Dynamic Terminal Airspace I	Develop concepts and algorithms for dynamically reconfiguring terminal airspace elements. These concepts will consider ASDO concepts in their design.	Number of algorithms, procedures developed.	Publication, white paper, or report.	11	4	NA	AS.3.3.08
AS.2.3.08		Flow Corridor Benefit Analyses	Perform benefits analyses of flow corridors in fast-time simulations incorporating procedures and capacity considerations learned from real time experiments.	% delay recovered over current sector design, corridor utilization.	Publication, white paper, or report	12	4	AS.2.3.03 AS.3.3.06 AS.3.3.07	AS.3.3.10
AS.2.4.05	APG	Initial Weather Translation Models	Complete development of initial models, algorithms, or concepts for translating deterministic and probabilistic weather forecasts and observations into ATM capacity impacts. These products will have sufficient information to address risk of implementing specific ATM decisions to both the user and air service provider.	Demonstrate a 5% improvement in the ability to estimate the capacity of a weather impacted region of airspace over traditional approaches that assume capacity reduction is equal to the percent area covered by VIL >= 3.	Conference or journal publication that describe the initial weather translation models	12	4	AS.1.4.05 AS.3.4.03 AS.3.4.04 AS.4.4.01	AS.2.4.06 AS.3.4.10

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.2.4.06		Refined Weather Translation Models	Develop and test a refined set of algorithms, models, or concepts for translating deterministic and probabilistic weather forecasts over multiple time-horizons compute ATM capacity impacts.	Demonstrate a 10% improvement in the ability to estimate the capacity of a weather impacted region of airspace over traditional approaches that assume capacity reduction is equal to the percent area covered by VIL >= 3.	Conference or journal publication describing the testing and development of weather translation models over multiple time-horizons	14	4	AS.2.4.05 AS.3.4.10	NA
AS.2.5.10		Identify Failure Modes for Off-nominal Studies	Identify major failure modes to be considered in the off-nominal functional allocation studies (ref: AS.4.5.01 & AS.4.5.02). Failure modes may be a function of technology, operating concept, and/or architecture. Analysis includes both component failure and human failure, e.g., human error.	Number of failure modes identified for each candidate operating concept to be evaluated in the functional allocation studies	Technical report written that documents the method and results of the analysis.	11	4	AS.1.5.03	AS.2.5.12 AS.4.5.01

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.2.5.11		Laboratory Integration of Multiple SA Algorithms into Simulation Testbeds	As testing of our candidate SA algorithms progresses, we will need to begin to evaluate algorithms in an integrated fashion. This could take several forms, among them: (a) testing ground-based strategic, tactical, and TCAS algorithms together; (b) testing airborne strategic, tactical, and TCAS algorithms together; (c) testing ground-based and airborne SA algorithms together; (d) testing ground-based strategic algorithms working in adjacent airspace regions (to probe boundary conditions). These integration studies will require a test bed that is capable of operating the respective algorithms. The objective of this milestone is to develop one or more of our simulation test beds to the point that it/they are capable of operating all of the relevant SA algorithm.	Number of algorithms integrated into each simulation test bed.	Test report(s) written that document the results for the respective algorithms that have been successfully integrated into the relevant test bed(s).	11	1	AS.3.5.03	AS.3.5.12
AS.2.5.12		Safety Assessment for SA Systems and Concepts	The research objective is to identify, analyze and validate hazards inherent to SA systems and concepts by methodically applying relevant safety-assessment techniques. Analysis should include relative severity, probability, exposure, and risk assessments for each hazard. Analysis should distinguish between hazards and risks that are common to any SA approach and those that are unique to a given approach.	Number of hazards identified, depth of analysis of each hazard	At least one technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	12	2	AS.1.5.01 AS.1.5.03 As.1.5.08	AS.3.5.16

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.2.5.13		Auto SA Performance: Dynamic Weather Constraints	Performance of candidate user-based and ANSP-based algorithms are evaluated, where conflict resolution is constrained by dynamic weather that renders some airspace unusable. The research objective is to determine the extent to which conflict-resolution algorithms can be made to respect and steer clear of potentially hazardous airspace. Assumptions, scenarios, uncertainty and metrics are common such that the experimental results generated by different algorithms can be directly compared.	SA performance measures for efficiency and safety.	At least one technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	11	1	AS.2.5.06	AS.3.5.07
AS.2.6.07	Critical	Procedures and Technologies for Initial ASDO Concept of Operations in Simple Airspace	Develop range of prototype procedures and technologies to support the ASDO initial concept definition, to include Tailored Arrivals, M&S, TACEC, etc. Testing and evaluation will include multiple batch and HITL simulations of that concept. Mixed operations with other concepts is desired but not required (see AS.3.6.03 & AS.3.6.05 for mixed operations Milestones).	* Metric will vary based on the type of procedure being researched, and the intended goal of that procedure.	Technical conference publication minimum, journal preferred.	11	4	AS.2.6.05 AS.2.6.09 As.3.6.02	AS.2.6.08 AS.3.6.03 AS.4.6.01
AS.2.6.12		High Fidelity Evaluation of Terminal Tactical Conflict Prediction & Resolution Function	Assess the air traffic controller and flight crew acceptability of the refined automated tactical conflict avoidance functionality in dense terminal airspace. Determine the acceptability of the refined avoidance function in terms of workload, situational awareness, and perceived safety using high-fidelity air traffic and flight deck simulators. Document changes to operational procedures needed to integrate avoidance function into the NAS.	Acceptable ratings for workload and situational awareness. Achieve false alert rate less than 1% and missed alert rate less than 1% for dense terminal airspace.	Publication at a technical conference minimum, journal preferred	12	4	AS.2.6.11	AS.3.6.08

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.2.6.14		Off-nominal Recovery Methods for Highly-Automated Super Dense Operations	The highly automated SDO concept option replaces terminal controller vectoring with automated strategic 4D trajectory management layered with automated tactical conflict avoidance and traditional collision avoidance functions. While providing separation assurance, these will not provide tactical reintegration of non-conforming operations (e.g. missed approach). This task will develop and evaluate in simulation the algorithms and roles/responsibilities associated with off-nominal recovery and reintegration of non-conforming (to strategic 4D trajectory) aircraft.	Reduction of terminal delay in off-nominal scenarios of 50%. Reinsertion of non-conforming aircraft with 90% success before conflict avoidance layer.	Technical conference publication minimum, journal preferred.	11	4	AS.3.6.04	AS.3.6.05 AS.3.6.06 AS.3.6.07
AS.2.6.15		Initial Scheduling Capability for Coordinated Arrival/Departure /Surface Operations for Single Airport	Develop terminal and surface schedulers for single airport operations that employ common interface definitions and representatively model information and constraints provided by other side of interface. SDO develops the terminal scheduler that models constraints needed by the surface scheduler. SESO develops the surface scheduler that models the constraints needed by terminal scheduler. Both schedulers should be built to explore different options of common SESO-ASDO interface defined by AS.3.6.04J	Degree to which Airspace and Airportal schedulers employ common interfaces for range of data exchange options.	Software code for Airspace and Airportal schedulers employing different (commonly defined) interfaces.	11	4	AS.2.6.06 AS.3.6.04	AS.3.6.05

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AS.2.6.16		Initial Scheduling Capability for Coordinated Arrival/Departure /Surface Operations for Metroplex	Develop terminal and surface schedulers for metroplex operations that employ common interface definitions and representatively model information and constraints provided by other side of interface. SDO develops the terminal scheduler that models constraints needed by the surface schedulers. SESO develops the surface scheduler that models the constraints needed by terminal scheduler. Both schedulers should be built to explore different options of common SESO-ASDO interface defined by AS.3.6.08	Degree to which Airspace and Airportal schedulers employ common interfaces for range of data exchange options.	Software code for Airspace and Airportal schedulers employing different (commonly defined) interfaces.	13	2	AS.2.6.15 AS.3.6.06	AS.3.6.08
AS.2.6.17		Initial Scheduling Capability for Integrated Arrival/Departure /Surface Operations for Metroplex	Develop combined terminal and surface scheduler for metroplex operations that employs common interface definitions and representatively models information and constraints provided by both sides of interface. Earlier, SDO and SESO developed separate terminal and surface schedulers that modeled the constraints needed by the other. The combined scheduler should be built to explore the different options of fully integrated SESO-ASDO schedules defined by AS.3.6.13.		Publication at a technical conference	14	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AP.1.C.07		Develop New LIDAR Algorithm	Develop New Algorithm, or Derivative of Existing Algorithm, for Processing LIDAR Measurements from Field Experiments to Accurately Determine Wake Vortex Position and Circulation	When processed using the new algorithm, LIDAR data from field experiments will provide position and circulation values consistent with established benchmark cases.	New algorithm, or derivative of existing algorithm, for processing LIDAR measurements from field experiments, and referenceable publication documenting quantitative assessment of the accuracy of LIDAR measured position and circulation strength and suggested methods for improving the accuracy of LIDAR data	11	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AP.1.C.08		Develop Improved Fast-Time Model	From assessment of current deterministic, fast-time, wake vortex prediction models, the "best" model or ensemble of models will be identified to use as the basis for development of a probabilistic model.	Model outputs will be assessed relative to Large Eddy Simulation (LES) results and available field data to estimate accuracy of predictions for various aircraft types and realistic ambient conditions.	Referenceable publication documenting assessment of fast-time models, the "best" model or ensemble of models to use as the basis for development of a probabilistic model, and the rationale for this recommendation.	11	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AP.1.C.09		Wake and Weather Data Collection for Robust Model Validation	Collect high-quality aircraft trajectory, wake and operating environment data sets for commercial transport aircraft approach, landing, takeoff and departure operations to use for robust validation of fast-time and probabilistic wake models. Data sets will be processed and quality checked on an on-going basis during the data collection period.	Aircraft position, wake location and strength, and relevant atmospheric conditions, such as wind, temperature, and turbulence at various altitudes, will be collected for transport aircraft operations into and out of a selected airport over a twelve-month period.		13	4		
AP.1.S.03		Develop and validate surface 4D trajectory model and taxi-clearance monitoring algorithm	Develop surface trajectory prediction/ synthesis algorithms and implement software into the surface simulation software. Uncertainties that will affect the trajectory prediction will be identified and sensitivity to prediction accuracy will be analyzed. Perform validation of predicted trajectories against flight data and/or data from simulations. Taxi clearance conformance monitoring algorithm will also be developed and implemented into the surface simulation software.	Resulting trajectory model predicts aircraft trajectories against actual trajectories within target tolerance approved by the project PI. Validation of the trajectory model will be performed based on the validation metrics to be developed in the milestone. The initial, largely subjective, validation will be updated in AP.3.S.03 as the performance of conflict detection algorithms using these trajectory models is assessed.	A final report of NRA contract documenting surface trajectory analyses, algorithms for trajectory modeling and conformance monitoring, and performance results.	11	2		AP.3.S.03 AP.3.S.04 AP.3.S.05 AP.3.S.07 AP.3.S.08 AP.3.S.09

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AP.2.C.08		Develop PDFs for Probabilistic Wake Model	Develop PDFs of wake vortex characteristics using existing LIDAR measurements for combination with best deterministic model(s) to produce probabilistic model.	Resulting probabilistic model will output, for any given time and location, the probability of a wake of a certain strength existing.	A probabilistic wake prediction model is created and verified that includes existing deterministic fast-time prediction models as the tool's core and pdf's of wake behavior based on varying key aspects of the environment and aircraft configurations.	11	4		
AP.2.C.09		Dynamic Aircraft Wake Spacing Tool Development	Using probabilistic fast-time wake model, develop decision support tool for adjusting aircraft wake avoidance spacing based on the particular aircraft involved and atmospheric conditions.	Decision support tool will provide recommended aircraft spacing based on wake avoidance with sufficient lead-time for controller to position aircraft for approach and landing.		13	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AP.2.C.10		Airport Runway Configuration Management (RCM) and Combined Arrival/Departure Runway Scheduling (CADRS) Algorithms for a Single Airport with Multiple Runways	For a single airport with multiple runways, research provides System Oriented Runway Management (SORM) algorithms (1) to support a proactive runway configuration management process, integrating airport equipment status, weather information, traffic demands, airline preferences, and controller workloads to cue operational decision making, and (2) to optimize the flow and distribution of landing and departing aircraft on an airport's active runway, improving resource utilization. Algorithms identify high-capacity solutions within the solution space of possible airport operations. Information exchanges between SORM algorithms and SESO-developed optimized surface operations capabilities, SDO-developed capabilities for management of inbound flows to the airport final approach paths and outbound flows from the active runways to the departure climb out paths, and human operator interfaces for tower and ground controller functions will be coordinated with the appropriate RFA. These interfaces and information exchanges may be emulated during algorithm development and stand-alone evaluation, as appropriate.	Metrics include airport throughput and/or total aircraft delays with a fixed demand during steady state weather conditions and during wind shifts requiring runway configuration changes. Benefit is validated by comparing throughput to that produced by subject matter experts (SMEs) in the same scenarios and by comparison to the estimated theoretical maximum throughput values (considering no uncertainties or unused slots). The target for the initial algorithm is performance at least equal to an experienced SME.	Referenceable publication, preferably a NASA TM or TP, documenting the algorithms, evaluation scenarios, and stand-alone performance	11	3		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AP.2.C.11		Extend RCM and Arrival/Departure Balancing Algorithms to Multiple Airports with Multiple Runways	System Oriented Runway Management algorithm capabilities for runway configuration management and combined arrival/departure runway management will be extended to address proximate airports that have multiple runways.	Metrics include airport throughput and/or total aircraft delays with a fixed demand during steady state weather conditions and during wind shifts requiring runway configuration changes. Benefit is validated by comparing throughput to that produced by subject matter experts (SME) in the same scenarios and by comparison to the estimated theoretical maximum throughput values (considering no uncertainties or unused slots). The target for the initial algorithm is performance at least equal to an experienced SME.	Referenceable publication, preferably a NASA TM or TP, documenting the algorithms, evaluation scenarios, and stand-alone performance	15	1		
AP.2.C.13		Wake Encounter Hazard Characterization	Modeling and simulation of flight environment, wake motion and decay, and airspace dynamics are used to develop quantifiable metrics for hazard level of wake aircraft combinations.			15	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AP.2.C.14 (was AP.3.C.14)		Integration of Dynamic Wake Spacing into Arrival/Departure Operations Tools	Dynamic wake spacing tool is integrated into arrival/departure operations decision support tools with prototype user interface.	Dynamic aircraft wake spacing will be factored into arrival stream scheduling with sufficient lead-time for controller to position aircraft for approach and landing. Airport throughput and surface operations will be compared with and without dynamic wake spacing.		15	4		
AP.2.S.10		Develop Interim Aircraft-Based CD&R Algorithms	Enhance aircraft-based low altitude, runway, and taxiway CD&R algorithms based on initial evaluations. Expand algorithms to enable accurate CD&R for expected NextGen capacity demands (up to 3 times current levels).	Metrics include nuisance, and missed alert rates, and time-to-conflict at detection for runway/low altitude/taxiway conflict via Monte Carlo simulations, at a minimum. Errors in surveillance data should be considered. The targets for acceptable rates for nuisance, and missed alerts will be determined through RTCA SC-186 WG1.	Conference paper reporting the performance of the algorithms of aircraft-based terminal area conflict detection and resolution.	12	4		AP.3.S.09 AP.3.S.08

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AP.2.S.11		Assess System Performance of Varying Options for 4D Taxi Clearance Information to Provide a Scientific Basis for Future Systems Requirements for Mature Surface Automation and Arrival/Departure Seamless Airspace Transition	Conduct medium-fidelity piloted simulations to evaluate surface automation concepts for 4D taxi and arrival/departure seamless airspace transition.	Metrics of interest in pilot conformance include time error at significant waypoints (runway or taxiway intersections), pilot workload or errors in secondary tasks, and incidents of incorrect turns or taxiway selection for varying level or options of automation interface.	Conference paper reporting the results of pilot-in-the-loop simulation to evaluate pilot interfaces, procedures, and ConOps for refined 4D taxi concepts and seamless airspace transition.A report documenting the effects of pilot workload of 4D taxi clearance ConOps using a formal analysis approach.	11	4		AP.3.S.07 AP.3.S.08 AP.3.S.09

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AP.2.S.12		Augment Surface Optimization and Environmental Algorithms	The research focus is to augment surface traffic optimization and environmental algorithms developed in previous milestones (AP.2.S.03, AP.1.S.04). Surface traffic optimization algorithms and environmental efficiency algorithms would be better coupled by directly or indirectly including environmental algorithms in the surface traffic optimization framework. The algorithms will be further augmented to address operational uncertainties, uncertainties due to human operators and off-nominal situations, maximizing operational and environmental efficiency while satisfying system constraints. Computational efficiency of solutions for real-time applications would be investigated.	For each optimization solution method, solve surface traffic planning problems for at least two major airports for both current-day traffic and future demand (e.g., 1.5x). Compare efficiency metrics (e.g., taxi/queue delays, reduction in fuel consumption) and airport throughput for each method. Compare robustness of the solutions against uncertainties.	Final reports documenting NRA efforts, including surface/environmental algorithms, integration of algorithms, simulation results of integrated systems. Conference papers describing performance of the algorithms in the presence of uncertainties and off-nominal situations.	11	4		AP.3.S.02 AP.3.S.05 AP.3.S.07 AP.3.S.08 AP.2.S.13

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AP.2.S.13		Investigate NextGen Surface Operations	The research focus is to characterize surface traffic operations envisioned by NextGen and develop surface optimization strategies to handle various traffic scenarios. Closely spaced parallel runways (CSPR) operations for both departures and arrivals will be considered in modeling and analysis surface traffic optimization. The operations of new types of aircraft, super jumbo aircraft as well as very light jets (VLJs), will also be considered as part of NextGen operations. New approaches of surface traffic management will be investigated.	Characterization of NextGen surface operations. Scenarios and modeling of NextGen surface operations. Performance metrics of surface operations (e.g., taxi delay, runway throughput) based on various optimization solutions will be measured upon fast-time simulations results for proposed NextGen scenarios.	Conference paper reporting the results of modeling and analysis of NextGen surface operations.	14	4		
AP.3.C.09		Concept of Operations and Requirements for Integrated Operations at a Single Airport	Develop definition of integrated operational elements for descent from cruise through landing and taxi to gate, and for taxi from gate through takeoff and climb to cruise for both human-centric and automated single airport operations. Define requirements for management of airborne resources (buffers, dynamic routing and service levels) and negotiation for surface resources (airport configurations, runways, taxiways, ramps, and gates).`	Results provide requirements for interfacing concepts, information exchange, and operational procedures developed within the CTD Project for culminating experiments to be conducted by SDO and SESO.	Completion of Requirements Review headed by CTD Project Scientist. NASA TM documenting concept of operations and requirements for integrated operations at a single airport	13	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AP.3.C.13		Evaluation of RCM and CADRS Tools in the Context of Other Tools and Systems Being Used by Traffic Flow Managers and Flight Crew	Airportal traffic flow management tools will be assessed in the context of other tools and systems being used by traffic flow managers and flight crews.	Impacts of adverse weather conditions and variations in traffic flow mix and rate will be assessed for multi-runway operations at a representative airport. Evaluation may be performed at a cooperating airport or through high-fidelity simulation.		15	4		
AP.3.S.03		Develop Ground-Based Surface CD&R Algorithms	Primary focus for the 1st year is to develop ground-based surface CD&R algorithms and integrate in NASA's simulation software. False, nuisance, and missed alert rates will be determined as function of key parameters such as time horizon. Primary focus for the 2nd year is to develop concepts and requirements for interactions between ATC and flight deck as well as design of alert/warning/resolution advisories. Interactions with aircraft-base CD&R will also be investigated.	Metrics include false, nuisance, and missed alert rates of conflict detection (for runway/taxiway incursion) via simulations. Assess time-to-conflict at detection of the conflict. Errors in surveillance data should be considered. The targets for acceptable rates for false, nuisance, and missed alerts will be determined through RTCA Sub-committee-186 Working Group 1.	A final report of NRA contract documenting the description of ground-based CD&R algorithms, performance evaluation results of the algorithms, and description of software design.	12	3		AP.3.S.04

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AP.3.S.04		Evaluate Ground-Based Conflict Detection and Resolution (CD&R) System	The research focus is to develop a prototype ground-based conflict detection and resolution (CD&R) system and evaluate userbility and performance of the system using HITL experiments. CD&R algorithms developed through the previous milestone (AP.3.S.03) will be integrated with the surface planning algorithms within SMS. Prototype user interfaces for the controller will also be developed, Communication between controllers and pilots will vary depending on the equipage of the aircraft.	SME acceptance of alert/warning/resolution advisories generated by the ground-based CD&R system on timing and format of displays. Metrics include qualitative measure of false, nuisance, and missed alert rates of conflict detection (for runway/taxiway incursion) via simulations. Assess time-to-conflict at detection of the conflict. Human factors analysis results in pilot/controller evaluation on alerting and resolution advisories.	Conference paper documenting the results of real-time simulations of the integrated ground CD&R system.	13	4		AP.3.S.09

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AP.3.S.05		Evaluate Initial Surface Trajectory-Based Operations with ATC in the Loop	Integrate, evaluate surface traffic algorithms (e.g., taxi and runway management), and conduct real-time simulations with controllers in the loop. The Surface Management System (SMS) provides taxi sequence advisories and clearances to the Ground controller, and takeoff sequence to the Local controller. The taxi conformance monitoring function displays alerts to controllers when an aircraft deviates from cleared taxi paths or fails to meet temporal requirements.	SME acceptance of traffic advisories. Performance of surface operations in terms of taxi delay and throughput with traffic demands increased up to 2X.	Conference paper reporting the results of real-time simulations of the integrated system of optimized surface planning, environmental planner, and taxi conformance monitoring.	12	4		AP.3.S.08
AP.3.S.07		Integrate 4D Taxi Clearance Compliance and Optimized Surface Planning	Conduct HITL simulations to evaluate performance of integrated flight deck technologies of 4D taxi clearance compliance displays and optimized surface traffic planning. The optimized taxi planning will generate taxi clearances that will include RTAs at pre-determined check points along the taxi route. The pilot displays will assist the pilot to follow the cleared taxi path and meet the times at those check points. Development of a prototype ATC decision support system to generate taxi clearance messages and communicate with the flight deck via data link is required. Surface optimization algorithms will be adjusted according to the evaluation of pilot performance of taxi clearance compliance.	Pilot acceptance of 4D taxi clearances and advisories generated by the AC-based taxi clearance compliance algorithms. Pilot performance of taxi clearance compliance (e.g., time of arrival errors) will be measured. Effectiveness of taxi clearance messages and conformance monitoring tool for the tower controller will be examined.	Conference paper reporting the results of real-time simulations of the integrated system of 4D taxi clearance compliance and optimized surface planning.	13	4		AP.3.S.09

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Q	Predecessor	Successor
AP.3.S.08		Integrate Surface Trajectory-Based Operations with Flight Deck Technologies	Conduct human-in-the-loop simulations to evaluate integrated surface traffic management, taxi conformance, pilot 4D taxi clearance compliance, and both ground- and aircraft-based CD&R technologies. Distributed simulations combining a cockpit simulator and ATC simulator with SMS may be used. Test scenarios will include both current operations and NextGen demand/fleet mix scenarios.	SME acceptance of traffic advisories, cockpit displays and alerts. Performance of pilot clearance compliance (e.g., time of arrival errors) with traffic demand increased up to 2X. Performance measure of surface operations (e.g., taxi delay, throughput). Performance measure of taxi conformance and CD&R algorithms (e.g., false, nuisance, missed alert rates)		14	4	AP.2.S.10	AP.3.S.09
AP.3.S.09		Conduct Field Evaluation of Initial Surface Trajectory-Based Operations	Develop concept of operations and requirements for the initial field evaluation of surface trajectory-based operations. Conduct a shadow mode field evaluation of surface operations that consist of surface taxi/runway management, taxi conformance monitoring, and ground-based surface CD&R.	Controller acceptance of traffic advisories and alerts. Measure controller workloads in performing tasks	Conference paper reporting the results of field evaluation of initial surface trajectory-based operations.	15	4		

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.1.4.06		Develop Linear/Nonlinear/ Dynamic Programming and Decomposition Methods for Advanced Traffic Flow Management	TFM approaches using current and future traffic scenarios in the NAS involves the computation of trajectories of all aircraft on a continental scale while satisfying the schedules of airlines and general aviation without exceeding the limitations imposed by airport constraints and en route airspace constraints due to weather and traffic. The problem is complex due to the large number of aircraft involved in the planning interval, number of decision-makers, and uncertainty of weather information. The optimization has to address equity issues and the robustness of solutions to changing conditions. A traditional approach to solving the non-linear stochastic optimization problem is to formulate it either as a Dynamic Programming problem or as a Multiple Integer Linear Programming problem. These methods have not been very successful in practice due to the curse of dimensionality and the sensitivity of the optimization to uncertainties in the problem. Current approaches to solving the problem in the NAS involve the use of heuristics. Any successful method to the TFM problem has to be executable in a timely manner, taking into account the co-ordination required to satisfy all decision-makers. The approach considered consists of decomposition methods resulting in a series of optimization problems, and a combination of the sub-optimization problems to present the total solution. The decomposition will be explored in three-domains: time, space (regions), and one based on procedures and functionality.	The decomposition methods are aimed at achieving a real-time planning capability (two minutes for a six-hour planning horizon) for NAS-level TFM problems.	Conference or journal publication describing the linear/nonlinear/dynamic programming and decomposition methods developed in support of this milestone.	11	4	AS.1.4.02 AS.1.4.04 AS.1.4.04 AS.1.4.05	AS.3.4.09

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.1.5.01		Alternative Criteria for Minimum Separation Standards	In the NextGen timeframe, it is expected that advanced SA technology and concepts may facilitate a move to new standards for safe separation. Such standards need not be defined by static symmetrical volumes centered about the aircraft, as is the case with today's "separation hockey puck," and the underlying risk analysis may consider different factors and uncertainties than were considered when today's separation standards were derived. This work is intended to be cooperative with the FAA, since the FAA will have ultimate responsibility for any safety case for NAS operations. The research objective will be to identify and evaluate new and alternative criteria for "minimum safe separation standards" for NextGen operations.	Number of alternative constructs proposed and evaluated. Reduction in risk and/or increase in capacity associated with a given construct.	At least one technical manuscript written and accepted for publication that meets the research objective as stated in the milestone description.	11	2		AS.2.5.12
AS.1.5.05		Verification and Validation Methodologies for SA Algorithms and Software	There is risk that the size and complexity of SA software may overwhelm the ability of conventional software V&V methods to assure a level of software quality acceptable for safety-critical systems. For example, conventional methods may be unable to provide adequate coverage or may be cost prohibitive. The research objective is to adapt existing V&V methodologies (e.g., Formal Methods, compositional approaches, adaptive approaches) or develop new ones in order to provide a credible path to achieving an acceptable level of V&V for this highly automated, highly complex application. Methodologies shall be applied to current candidate SA algorithms.	Code coverage, path coverage, V&V time, V&V cost, software robustness.	At least one technical manuscript written and submitted or submitted for publication that meets the research objective as stated in the milestone description.	12	2	AS.1.5.08 AS.3.5.16	

B-2. Current Milestones FY2011 – FY2015

Milestone ID	Key Milestone	Title	Description	Planned Metric	Exit Criteria	Scheduled Completion FY	Scheduled Completion Q	Predecessor	Successor
AS.1.5.08		Verification and Validation Technologies for Analysis of N-Aircraft SA Algorithms	Develop mathematical proof of the safety property for N aircraft independently executing the CD&R algorithm.	Number and scope of assumptions required to complete the proof.	At least one technical manuscript written and submitted for publication that meets the research objective as stated in the milestone description.	11	4	AS.1.5.06	AS.1.5.06 AS.2.5.12

B-3. Milestone Schedule for FY2011 – FY2015

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B-4. Key Milestones FY2011 – FY2012

Appendix B-4 contains a listing of key milestones for each RFA planned for FY2011 – FY2012. The Project tracks key milestones at the Program and Directorate level according to the following designations:

- Critical = Milestones provided by the Project and Program in response to Congressional Questions For the Record 2007.
- APG = Agency Performance Goal. The APG is an element within the Agency Performance Plan.
- HPPG = High Priority Performance Goal. Support Program response to OMB.
- CBJ = Congressional Budget Justification = APG and HPPG

Table 3. Key Milestones for FY2010 – FY2013

FY	Milestone Number	TYPE	Center Supporting
11	AS.2.6.07	Critical	Ames, Langley
11	AS.3.5.07	Critical	Ames, Langley
11	AS.3.6.11	APG	Ames
11	AS.4.4.01	Critical	Ames
12	AS.2.4.05	APG	Ames
12	AS.3.6.06	Critical	Ames, Langley
12	AS.3.6.10	APG	Ames, Langley
13	AS.4.5.01	Critical	Ames, Langley

B-4. Key Milestones FY2011 – FY2012

FY2011 performance Plan From the FY 2011 Annual Performance Goals (APGs) and Outyear Commitments for the ARMD FY 2011 Integrated Budget and Performance Document (IBPD)

APG 11AT05	Evaluate initial terminal tactical conflict prediction and resolution functions.	Airspace Systems (NextGen Concepts and Technology Development Project)
Success Criteria: *Green* – Complete and document a Human-In-The-Loop simulation to evaluate an experimental approach for conducting investigations of infrequent tactical aircraft-to-aircraft conflicts (i.e., missed, late and false conflict alerts). *Yellow* – Complete a fully-integrated system evaluation to prepare for a Human-In-The-Loop simulation to evaluate an experimental approach for conducting investigations of infrequent tactical aircraft-to-aircraft conflicts (i.e., missed, late and false conflict alerts). *Red* – Complete an evaluation of individual, non-integrated systems to prepare for a Human-In-The-Loop simulation to evaluate an experimental approach for conducting investigations of infrequent tactical aircraft-to-aircraft conflicts (i.e., missed, late and false conflict alerts)		

FY2012 Proposed APG

APG 12AT5	**Develop initial weather translation models.**	Airspace Systems (NextGen Concepts and Technology Development Project)
Success Criteria: *Green:* Demonstrate an ability to estimate the weather-impacted traffic capacity of a region of airspace (e.g., a sector) or an airport in a fifteen-minute interval within 30% of the actual weather-impacted capacity over a one-hour prediction interval on a set of "bad" weather days. Since the actual weather-impacted capacity of a region of airspace or an airport is unknown, this capacity will be taken to be the observed peak aircraft count over the corresponding 15-min period. *Yellow:* Demonstrate an ability to estimate the weather-impacted traffic capacity of a region of airspace (e.g., a sector) or an airport in a fifteen-minute interval within 45% of the actual weather-impacted capacity over a one-hour prediction interval on a set of "bad" weather days. Since the actual weather-impacted capacity of a region of airspace or an airport is unknown, this capacity will be taken to be the observed peak aircraft count over the corresponding 15-min period. *Red:* Demonstrate an ability to estimate the weather-impacted traffic capacity of a region of airspace (e.g., a sector) or an airport in a fifteen-minute interval within 50% of the actual weather-impacted capacity over a 30-minute prediction interval on a set of "bad" weather days. Since the actual weather-impacted capacity of a region of airspace or an airport is unknown, this capacity will be taken to be the observed peak aircraft count over the corresponding 15-min period.		

Appendix C: FY2010 Milestone Record Activity

Appendix C contains the following Milestone Records:

- C-1. Dynamic Airspace Configuration (DAC)
- C-2. Traffic Flow Management (TFM)
- C-3. Separation Assurance (SA)
- C-4. Super-Density Operations (SDO)
- C-5. Safe and Efficient Surface Operations (SESO)

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Appendix D. NextGen CTD Resources

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Appendix E. NASA Facilities and Laboratories

Facilities, Laboratories and Tools used in FY2011 include:

Milestone Facility / Milestone	**Milestone Title Description**

NASA Supercomputer

AP.1.C.07	Develop New LIDAR Algorithm
AP.1.C.08	Develop Improved Fast-Time Model
AP.2.C.08	Develop PDFs for Probabilistic Wake Model

High-End Computing to run LIDAR Simulation

AP.1.C.07	Develop New LIDAR Algorithm

Fast-Time Simulation Platform

AP.2.C.10	Airport Runway Configuration Management (RCM) and Combined Arrival/Departure Runway Scheduling (CADRS) Algorithms for a Single Airport with Multiple Runways
AP.2.C.11	Extend RCM and Arrival/Departure Balancing Algorithms to Multiple Airports with Multiple Runways

Flight Deck Display Research Laboratory

AS.2.6.07	Procedures and Technologies for Initial ASDO Concept of Operations in Simple Airspace

Air Traffic Control laboratory Ames N210 Facility

AS.3.3.11	Operator Roles and Responsibilities
AS.3.5.19	Near-term Concept for Trajectory-based Operations with Datalink Simulations and Analysis
AS.2.6.07	Procedures and Technologies for Initial ASDO Concept of Operations in Simple Airspace
AS.3.6.03	Evaluation of Single Airport Operations Using Medium-term Technologies.
AS.3.6.05	Evaluate Single Airport Operations Using Late-term Technologies.
AS.3.6.11	Initial Evaluation of Terminal Tactical Conflict Prediction and Resolution Functions

Airspace Operations Laboratory

AS.3.3.06	Validate Flow Corridors Feasibility
AS.3.3.07	Interactions Between Airspace Classes
AS.2.6.14	Off-nominal Recovery Methods for Highly-Automated Super Dense Operations

Cockpit Motion Facility

AS.3.6.09	Evaluation of Interval Management Procedures to a Single Airport with Dependent Parallel Runways
AS.3.6.10	Evaluation of Interval Management Procedures to a Single Airport with Delegated Separation

AP.2.S.10	Develop Interim Aircraft-Based CD & R Algorithms

ACES Airspace Concept Evaluation System

AS.1.5.01	Alternative Criteria for Minimum Separation Standards
AS.2.5.13	Auto SA Performance: Dynamic Weather Constraints

FAA Technical Center

AS.1.5.01	Alternative Criteria for Minimum Separation Standards

Air Traffic Operations Laboratory

AS.2.5.11	Laboratory Integration of Multiple SA Algorithms into Simulation Testbeds
AS.3.5.13	Auto SA simulation: Mixed Operations Airspace Under Nominal Conditions
AS.3.6.09	Evaluation of Interval Management Procedures to a Single Airport with Dependent Parallel Runways
AP.2.S.10	Develop Interim Aircraft-Based CD & R Algorithms

Center TRACON Automation System

AS.3.5.19	Near-term Concept for Trajectory-based Operations with Datalink Simulations and Analysis
AS.4.4.01	Develop and Test Early Integrated Traffic Flow Management (TFM) Concepts for Advanced Traffic Flow Management to Accommodate User Preferences, Reduce Delays and Increase Efficiency Under All-weather conditions

Crew-Vehicle Systems Research Facility

AS.3.3.11	Operator Roles and Responsibilities
AS.3.5.19	Near-term Concept for Trajectory-based Operations with Datalink Simulations and Analysis

Human-Centered Systems Lab

AP.2.S.11	Assess System Performance of Varying Options for 4D Taxi Clearance Information to Provide a Scientific Basis for Future Systems Requirements for Mature Surface Automation and Arrival/Departure Seamless Airspace Transition

737 Flight Simulator

AP.2.S.11	Assess System Performance of Varying Options for 4D Taxi Clearance Information to Provide a Scientific Basis for Future Systems Requirements for Mature Surface Automation and Arrival/Departure Seamless Airspace Transition

Future ATM Concepts Evaluation Tool

AS.1.4.06	Develop Linear/Nonlinear/Dynamic Programming and Decomposition Methods for Advanced Traffic Flow Management
AS.4.4.01	Develop and Test Early Integrated Traffic Flow Management (TFM) Concepts for Advanced Traffic Flow Management to Accommodate User Preferences, Reduce Delays and Increase Efficiency Under All-weather Conditions
Milestone Facility / Milestone	Milestone Title Description

NASA Supercomputer

AP.1.C.07	Develop New LIDAR Algorithm
AP.1.C.08	Develop Improved Fast-Time Model
AP.2.C.08	Develop PDFs for Probabilistic Wake Model

High-End Computing to run LIDAR Simulation

AP.1.C.07	Develop New LIDAR Algorithm

Fast-Time Simulation Platform

AP.2.C.10	Airport Runway Configuration Management (RCM) and Combined Arrival/Departure Runway Scheduling (CADRS) Algorithms for a Single Airport with Multiple Runways
AP.2.C.11	Extend RCM and Arrival/Departure Balancing Algorithms to Multiple Airports with Multiple Runways

Flight Deck Display Research Laboratory

AS.2.6.07	Procedures and Technologies for Initial ASDO Concept of Operations in Simple Airspace

Air Traffic Control laboratory Ames N210 Facility

AS.3.3.11	Operator Roles and Responsibilities
AS.3.5.19	Near-term Concept for Trajectory-based Operations with Datalink Simulations and Analysis
AS.2.6.07	Procedures and Technologies for Initial ASDO Concept of Operations in Simple Airspace
AS.3.6.03	Evaluation of Single Airport Operations Using Medium-term Technologies.
AS.3.6.05	Evaluate Single Airport Operations Using Late-term Technologies.
AS.3.6.11	Initial Evaluation of Terminal Tactical Conflict Prediction and Resolution Functions

Airspace Operations Laboratory

AS.3.3.06	Validate Flow Corridors Feasibility
AS.3.3.07	Interactions Between Airspace Classes
AS.2.6.14	Off-nominal Recovery Methods for Highly-Automated Super Dense Operations

Cockpit Motion Facility

AS.3.6.09	Evaluation of Interval Management Procedures to a Single Airport with Dependent Parallel Runways
AS.3.6.10	Evaluation of Interval Management Procedures to a Single Airport with Delegated Separation
AP.2.S.10	Develop Interim Aircraft-Based CD & R Algorithms

ACES Airspace Concept Evaluation System

AS.1.5.01	Alternative Criteria for Minimum Separation Standards
AS.2.5.13	Auto SA Performance: Dynamic Weather Constraints

FAA Technical Center

AS.1.5.01	Alternative Criteria for Minimum Separation Standards

Air Traffic Operations Laboratory

AS.2.5.11	Laboratory Integration of Multiple SA Algorithms into Simulation Testbeds
AS.3.5.13	Auto SA simulation: Mixed Operations Airspace Under Nominal Conditions
AS.3.6.09	Evaluation of Interval Management Procedures to a Single Airport with Dependent Parallel Runways
AP.2.S.10	Develop Interim Aircraft-Based CD & R Algorithms

Center TRACON Automation System

AS.3.5.19	Near-term Concept for Trajectory-based Operations with Datalink Simulations and Analysis
AS.4.4.01	Develop and Test Early Integrated Traffic Flow Management (TFM) Concepts for Advanced Traffic Flow Management to Accommodate User Preferences, Reduce Delays and Increase Efficiency Under All-weather conditions

Crew-Vehicle Systems Research Facility

AS.3.3.11	Operator Roles and Responsibilities
AS.3.5.19	Near-term Concept for Trajectory-based Operations with Datalink Simulations and Analysis

Human-Centered Systems Lab

AP.2.S.11	Assess System Performance of Varying Options for 4D Taxi Clearance Information to Provide a Scientific Basis for Future Systems Requirements for Mature Surface Automation and Arrival/Departure Seamless Airspace Transition

737 Flight Simulator

AP.2.S.11	Assess System Performance of Varying Options for 4D Taxi Clearance Information to Provide a Scientific Basis for Future Systems Requirements for Mature Surface Automation and Arrival/Departure Seamless Airspace Transition

Future ATM Concepts Evaluation Tool

AS.1.4.06	Develop Linear/Nonlinear/Dynamic Programming and Decomposition Methods for Advanced Traffic Flow Management
AS.4.4.01	Develop and Test Early Integrated Traffic Flow Management (TFM) Concepts for Advanced Traffic Flow Management to Accommodate User Preferences, Reduce Delays and Increase Efficiency Under All-weather Conditions

Major Lab Descriptions:

- **Air Traffic Operations Laboratory (ATOL)**

  The Langley Air Traffic Operations Laboratory (ATOL) is a multi-fidelity, part task, air traffic simulation environment designed to explore inter-aircraft, aircraft/airspace, and air/ground interactions. The ATOL is capable of hosting both batch and human-in-the-loop (HITL) studies to investigate advanced flight deck technologies and air traffic management (ATM) concept-level operations research (flight procedures, human decision making, situational awareness, transfer of authority and responsibility) to meet the needs of the Next Generation Air Transportation System (NextGen).

The ATOL is comprised of over 500 computing platforms (individual PCs and Blades), each simulating an individual aircraft. Each aircraft simulation includes 6 degree-of-freedom aircraft models in real-time code, Flight Management System (FMS) and Computer (FMC) emulation, generic Boeing glass cockpit flight displays, auto-flight and auto-throttle systems emulation, Automatic Dependent Surveillance-Broadcast (ADS-B) model, ARINC 429 avionics bus emulation, and Class III Electronic Flight Bag emulation. Hundreds more aircraft with lower fidelity aero-performance models may be combined with the high fidelity aircraft simulations in order to perform high-density airspace studies. Twelve single-pilot stations are used to support studies and simulations involving active airline pilots as participants. The ATOL also hosts five Air Traffic Control (ATC) stations with voice and data link communications to enable HITL studies involving both pilot test subjects and confederate air traffic controllers. The ATOL may be connected, through High Level Architecture (HLA) gateways to other facilities, e.g. full mission, high-fidelity flight decks or air traffic control facilities around the country to leverage their capabilities.

- **ARC Crew-Vehicle Systems Research Facility (CVSRF)**

  The Crew-Vehicle Systems Research Facility (CVSRF) is an unparalleled national resource that supports NASA, the FAA, and many industry research programs. Designed to provide researchers with an environment where they can study how and why aviation errors occur, CVSRF stands out in the area of human factors research. Our goal is to offer researchers a suite of simulation facilities and utilities that can be used to analyze flight crew performance and to develop and improve new simulation and training tools. CVSRF houses several simulators capable of full-mission simulation. These simulators interact with each other (as well as with other SimLabs facilities) by means of a High Level Architecture (HLA), allowing for enormous flexibility and customization. Using CVSRF’s highly sophisticated simulators (the Boeing 747-400, the Advanced Concepts Flight Simulator, and the Air Traffic Control (ATC) Laboratory), researchers are able to study the effects of automation and advanced instrumentation on human performance. Through Virtual Airspace Simulation Technologies (VAST), CVSRF is integrated with FutureFlight Central (FFC) and the Vertical Motion Simulator (VMS) to provide simultaneous cockpit and air traffic control perspectives. This unique capability enables systems-level analyses of concepts across multiple domains and creates the building blocks for simulating more of the operations encompassed within the national airspace system. CVSRF’s flight simulators have six-degree-of-freedom motion capability and built-in data collection capabilities – a great benefit to researchers conducting real-time simulations. An important focus at CVSRF includes the testing and evaluation of new flight systems and technologies. The CVSRF provides the capability to evaluate modern air traffic control procedures and define specialized criteria for the future of aviation using real-time and non-real-time full-mission simulation–with or without a human in the loop. The ability to conduct high-fidelity, full-mission simulations transforms the experience for the pilot and flight crew from one of simply flying the aircraft on its own to a fully interactive process in which the crew can engage in “gate-to-gate” procedures and communications with a variety of ATC controllers and scenarios. CVSRF’s capacity to perform such high-fidelity simulations sets us apart from other testing facilities.

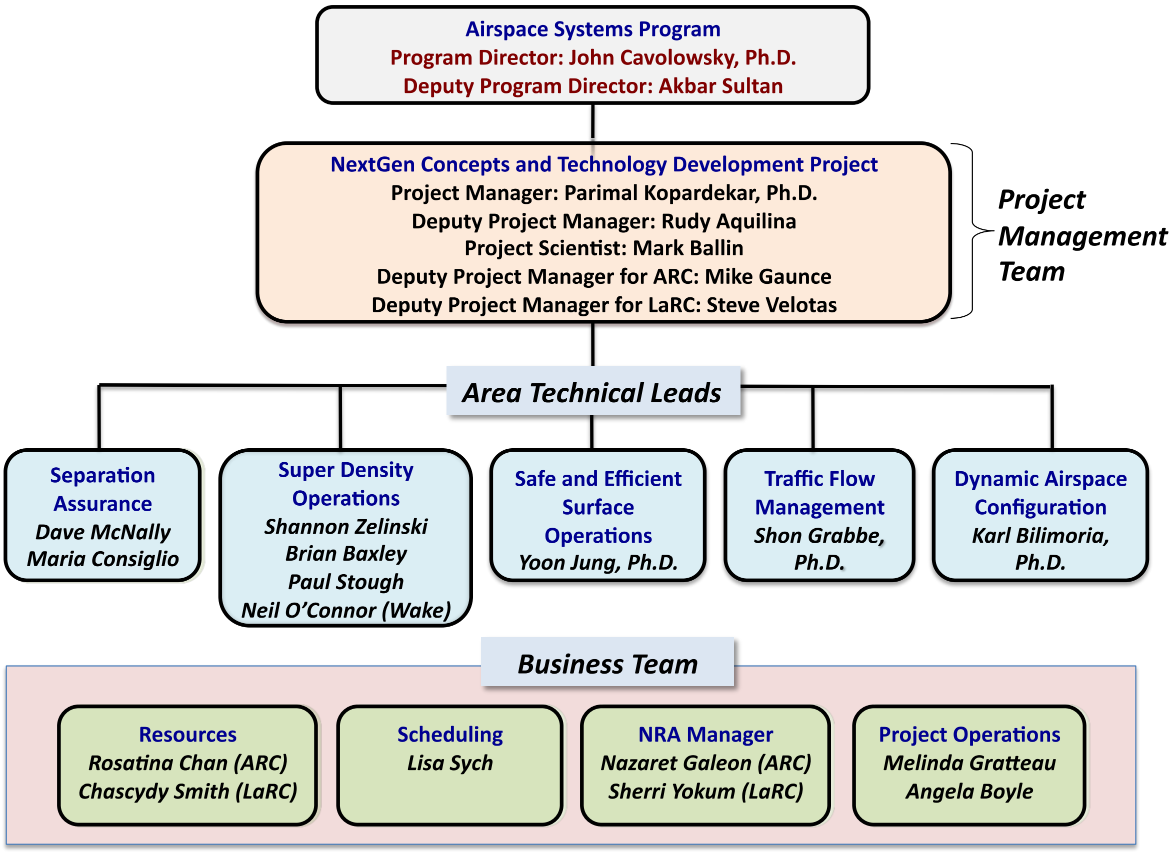
- **ARC Airspace Operations Laboratory (AOL)**

  The Airspace Operations Lab evaluates air traffic management (ATM) concepts and explores human-system interaction issues in a high-fidelity human-in-the-loop simulation environment designed to allow rapid prototyping of NextGen concepts. This environment allows simulations of aircraft, ATM systems and communication infrastructure for both current day operations and a variety of future, highly automated concepts. Controller workstations are realistic emulations of today's en route, Terminal Radar Approach Control (TRACON) and oceanic systems. They also include a full suite of advanced decision support tools and automated functions for conflict detection and resolution, trajectory planning, scheduling and sequencing, and managing advanced levels of airborne equipage. The main goal of the research in the AOL is to evaluate future ATM systems and associated human-system interactions. One of the main challenges of examining future ATM systems is that future operations are generally underspecified in their descriptions of system functionality, procedures, performance measurements, and system status measurements (workload, amount of communication, and similar measurements). The AOL's findings help the ATM community to understand potential human performance and human system interactions issues related to NextGen concepts. The results can lead to better understanding of roles and responsibilities for human operators and automation in future ATM systems.

- **LaRC Cockpit Motion Facility (CMF)**

  The LaRC Cockpit Motion Facility (CMF) is a multifaceted motion and fixed-base flight simulation research laboratory. It is designed to support advanced flight deck design research and vehicle operations research for Aviation Safety and Airspace Systems for the Next Generation Air Transportation System – i.e. research in which motion cues are critical to the realism of the experiments being conducted. The Cockpit Motion Facility is made up of fixed-base simulator sites and one motion-base simulator site. The simulators are the Research Flight Deck Simulator (all-glass reconfigurable commercial transport cockpit with programmable sidestick control inceptors), the Integration Flight Deck Simulator (conventional commercial transport cockpit with programmable wheel/column control inceptors – considered equivalent to FAA certified Level D simulator), and the Generic Flight Deck Simulator (all-glass reconfigurable futuristic cockpit with interchangeable programmable control inceptors). Each of these simulators is designed to operate as a fixed-base simulator or as a motion-base simulator when the simulator is put onto the state-of-the-art high-performance, 76-inch six-degree-of-freedom synergistic motion system. The simulators can be tied to the NASA LaRC Air Traffic Operations Laboratory (ATOL) as well as simulation facilities at other NASA Centers, DOD facilities, FAA facilities, commercial facilities, and university facilities to conduct large-scale multivehicle simulations.

Appendix F. Project Management Structure



Appendix G: FY2011 CTD Project Work Breakdown Structure

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Appendix H. Awarded NRA Tasks

Round 1 FY06 - 07			
TFM	University of Maryland, College Park	Ball	Dynamic, Stochastic Models for Managing Air Traffic Flows
TFM	Georgia Tech Research Corp.	Clarke	Approaches to TFM in the Presence of Uncertainty
TFM	Washington State University	Roy	Control-theoretic Design and Numerical Evaluation of Traffic Flow Management Strategies under Uncertainty
TFM	University of California, Berkeley	Bayen	A Unified Approach to Strategic Models and Performance Evaluation for Traffic Flow Management
TFM	Massachusetts Institute of Technology	Hansman	Cognitively Based Traffic Complexity Metrics for Future NGATS Concepts of Operations
TPSU	L-3 Communications Titan Corp.	Vivona	Development of Algorithms and Techniques for Trajectory Prediction Accuracy and Uncertainty Estimation
TPSU	L-3 Communications Titan Corp.	Idris	Trajectory Flexibility Preservation and Constraint Minimization for Distributed ATM with Self-Limiting Traffic Complexity
SA	Purdue University	Landry	Analysis and development of strategic and tactical separation assurance algorithms
SA	University of California, Santa Cruz	Erzberger	Concepts and Algorithms for Automated Separation Assurance
SA	Stanford University	Tomlin	Integrating Collision Avoidance and Tactical Air Traffic Control Tools
SA	California State University, Long Beach	Strybel	Metrics for Operator Situation Awareness, Workload, and Performance in Automated Separation Assurance Systems
SDO	Metron Aviation	Krozel	Mitigation of Weather Impacts in Dense Terminal Airspace
SDO	Massachusetts Institute of Technology	Hansman	Optimization of Super-Density Multi-Airport Terminal Area Systems in the Presence of Uncertainty
SLDAST	San Jose State University	Freund	Computational Models of Human Workload: Definition, Refinement, Integration, and Validation in Fast-time National Airspace Simulations
SLDAST	George Mason University	Sherry	Analysis of NGATS Sensitivity to Gaming
Round 2 FY07			
PBS	CSSI, Inc.	Mondoloni	A Method for System Performance Evaluation from Air/Ground Application Performance Under Various Operational Concepts
PBS	Georgia Institute of Technology	Volovoi*	A Conceptual and Computational Framework for Identifying and Predicting the Performance of Novel Airspace Concepts of Operation
PBS	Intelligent Automation, Inc.	Manikonda	Multi-Fidelity CNS Models to Support NGATS Concepts

TFM	Optimal Synthesis, Inc.	Menon	Multi-Resolution Queuing Models for Analyzing the Impact of Trajectory Uncertainty and Precision on NGATS Flow Efficiency
TFM	University of California, Berkeley	Hansen	Advanced Stochastic Network Queuing Models of the Impact of 4D Trajectory Precision on Aviation System Performance
TFM	Mosaic ATM, Inc.	Cook	Modeling Non-Convective Weather Impacts on En Route Traffic Flow Management
TFM	Metron Aviation	Krozel	Translation of Weather Information to Traffic Flow Management Impacts
TFM	L-3 Communications Corp.	Idris	Feasibility and Benefit Assessment of a Concept of Operations for Collaborative Traffic Flow Management
TPSU	L-3 Communications Corp.	Vivona	Analysis and Comparison of Capabilities and Requirements for Aircraft Trajectory Prediction Technologies
TPSU	University of Minnesota	Zhao	A Unified Approach to the Documentation, Analysis, and Cross-Comparison of Trajectory Predictors
DAC	Mosaic ATM, Inc.	Brinton	Assessment of Concepts and Algorithms for Dynamic Airspace Allocation
DAC	Metron Aviation, Inc.	Hoffman	Overall Airspace Organization and Dynamic Airspace Allocation Schemes
DAC	CSSI, Inc.	Rodgers	The Development of Concepts of Operation and Algorithms to support Dynamic Airspace Allocation as a Function of Equipage, Traffic Density and Weather
SDO (METRO)	Mosaic ATM, Inc.	Atkins	Investigating the Nature of and Methods for Managing Metroplex Operations
Round 3 FY08			
SDO	Purdue University	Landry	Transition to Super Density Operations Capability – 2015 Timeframe
SDO	San Jose State University	Gore	Identification of NextGen Air Traffic Control and Pilot Performance Parameters for Human Performance Model Development in the Transitional Airspace
PBS	Raytheon Intelligence and Information Systems	Finkelsztein	Weather Scenarios Generator and Server for the Airspace and Traffic Operations Simulation
PBS	Sensis Seagull Technology Center	Peters	Integration of Weather Data into Airspace and Traffic Operations Simulation (ATOS) for Trajectory Based Operations Research
PBS	Raytheon Intelligence and Information Systems	Finkelsztein	A Four Dimensional Dynamic Required Navigation Performance Construct to Support NextGen Concepts
SA	Logistics Management Institute	Hemm	Safety Analysis of Today's Separation Assurance Function
SLDAST	The University of Virginia	Patek	Multi-scale Tools for Airspace Modeling and Design
SLDAST	San Jose State University	Lee	Identification, Characterization, and Prioritization of Human Performance Issues and Research in the Transition to Next

			Generation Air Transportation System (NEXTGEN)
SLDAST	Sensis Seagull Technology Center	Hunter	Linking Airspace Modeling and Simulation Tools of Variable Fidelity and System Scope
SLDAST	Optimal Synthesis, Inc.	Menon	Open-Source based Software Systems for Linking Disparate Software Components
Round 4 FY09			
TFM	George Mason University.	Hoffman	Market-based and Auction-based Models and Algorithms for En-route Allocation and Configuration
Round 5 FY09			
	No awards.		
Round 6 FY10			
SA	LMI	Hemm	Assessment of System Safety and Risks for NextGen Concepts and Technologies
SDO	Metron Aviation, Inc	Krozel	Mitigation of Off-Nominal Events in Super-Density Operations
TFM	Mosaic ATM, Inc	Cook	Weather Translation Modeling to Support Traffic Flow Management
TFM	Metron Aviation, Inc	Krozel	Weather Translation Models for Strategic Traffic Flow Management
TFM	Sensis Corp	Saraf	TFM Algorithms and Modeling
DAC	Engility	Idris	A Decision Theoretic Approach to Estimating Airspace Capacity Based on Risk Mitigation
TFM	Sensis Corp	Hunter	Weather Capabilities: Translation Modeling
SA	SAIC	Chung	Datalink Communication Performance Analysis for Distributed Separation Assurance System Architectures
ARRA NRA			
SESO	Sensis Corp	Waldron	Development of Ground-Based Surface Conflict Detection and Resolution Algorithms
SESO	Optimal Synthesis, Inc	Cheng	Surface Conflict Detection and Resolution with Emphasis on Trajectory-Based Operations
Round 7 FY11			
	5 NRA Awards in negotiation		

Appendix I. TRL Responsibilities Between Projects

TRL (NASA SE Manual)	Activity	Lead Project
1. Basic principles observed and reported	Bottoms-up, inductive logic, researcher generating an idea -Top-down domain studies to generate better understanding of domain characteristics and constraints; identify potential solution path	CTD
2. Technology concept and/or application formulated	Formulate individual concepts/ideas; algorithms formulated to address a specific operational need Potential solution paths further analyzed; benefit assessments to identify possible impacts and to identify technological challenges (R&D needs)	CTD
3. Analytical and experimental critical function and/or characteristic proof of concept	Conduct initial analysis to show the merits of the concept/ideas/algorithms Conduct thorough benefit assessments; evaluate potential benefits of combined concepts	CTD
4. Component and/or integrated components validation in laboratory environment	Conduct validation of initial integrated (as needed) concept prototype in a laboratory environment Develop initial technology prototype; validation in laboratory environment.	CTD and SAIE
5. Component and/or integrated components validation in relevant environment	Develop relevant environment, scenarios, and integrate multiple components Continue to mature a concept and technology based on simulation results	SAIE
6. System/subsystem model or prototype demonstration in a relevant environment	Integrate technology prototype in high-fidelity relevant environment; conduct testing and evaluation; update benefit, safety, and human factors assessments. Provide the concept/ technology prototype, description and algorithms for necessary demonstration	SAIE
7. System prototype demonstration in an operational environment	Support transition of technology to FAA; prototype modification to address site-specific operations; integration with other facility tools that operate in same environment Provide concept/algorithm modifications and descriptions as necessary to support technology transition	SAIE and CTD
8. Actual system completed and demonstrated in operational environment	No Project responsibility	No Project responsibility
9. Actual system operationally proven through use in operational environment	No Project responsibility	No Project responsibility

Appendix J. Formal Agreements

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Appendix K. Knowledge Dissemination

Knowledge Dissemination (from the FY10 Annual Review)

	DAC	SA	SDO	SESO	TFM	Total
AIAA: Atmospheric and Space Environments			5			**5**
AIAA: Aviation Technology, Integration and Operations	13	6	9	6	14	**48**
AIAA: Guidance, Navigation, and Control Conference	5	2		3	15	**25**
AIAA: Infotech@Aerospace 2010 Conference			1		1	**2**
AIAA: Modeling and Simulation Technologies Conference			2		4	**6**
Digital Avionics Systems Conference	3*	5	4	2	1	**15**
Institute of Electrical and Electronics Engineers Control Systems Magazine					1	**1**
International Council of the Aeronautical Sciences	2	1			1	**4**
Air Traffic Control Quarterly	1	1		1	1	**4**
Journal of Aircraft			1		1	**2**
Journal of Airspace Computing, Information and Communication	1				1	**2**
Journal of Guidance, Control and Dynamics	1				1	**2**
Totals	**26**	**15**	**22**	**12**	**41**	**116**

* One DAC paper also addressed TFM issues.

Appendix L. Milestone Change Log

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Appendix M. Review Comments and Discussion

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Appendix N. Acronyms and Abbreviations

4D	Four-dimensional (latitude, longitude, altitude, and time)
4D-ASAS	Four-dimensional airborne separation assurance system
AA	Associate Administrator
AAC	Advanced Airspace Concept
ACES	Airspace Concept Evaluation System
AFRL/IF	Air Force Research Laboratory, Information Directorate
AIAA	American Institute for Aeronautics and Astronautics
AOL	Airspace Operations Laboratory
ARC	Ames Research Center
ARMD	Aeronautics Research Mission Directorate
ARRA	American Recovery and Reinvestment Act
AS	Airspace Systems
ASP	Airspace Systems Program
ASTOR	Aircraft Simulation for Traffic Operations Research
ATC	Air Traffic Control
ATM	Air Traffic Management
ATOL	Air Traffic Operations Laboratory
ASA	Automated Separation Assurance
ATSP	Air Traffic Service Providers
AvSP	Aviation Safety Program
CADOM	Coordinated Arrival/Departure Operations
CAST	Commercial Aviation Safety Team
CD	Center Director
CDM	Collaborative Decision Making
CD&R	Conflict Detection and Resolution
CD&T Project	Concept Development and Technology Project
CFO	Chief Financial Officer
CNS	Communication, Navigation and Surveillance
COMM/OBL/ACCR	Commitments/Obligations/Accruals
COTR	Contracting Officer Technical Representative
CS	Civil Servant
CTD	Concepts and Technology Development
CTFM	Collaborative Traffic Flow Management
DAC	Dynamic Airspace Configuration
DFRC	Dryden Flight Research Center
DOD	Department of Defense
DOT	Department of Transportation
DPM	Deputy Project Manager
DPMF	Deputy Project Manager for a Center
DST	Decision Support Tools
EFICA	Efficient Flow in Congested Airspace
FAA	Federal Aviation Administration
FACET	Future ATM Concept Evaluation Tool
FAF	Final Approach Fix

EDA	En Route Descent Advisor
FMS	Flight Management Systems
FTE	Full-time Equivalent
FY	Fiscal Year
GDP	Gross Domestic Product
HCI	Human-Computer Interaction
HITL	Human-in-the-Loop
HQ	Headquarters
IADS	Integrated Arrival/Departure/Surface
IEEE	Institute of Electrical and Electronic Engineers
IIFD	Integrated Intelligent Flight Deck
INC	Including
IP	Intellectual Property
IPT	Integrated Product Team
ITA	International Transport Association
ITAR	International Traffic in Arms Regulation
JPDO	Joint Planning and Development Office
JView	software visualization package developed by AFRL
LaRC	Langley Research Center
LNG	Low Noise Guidance
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NextGen	Next Generation Air Transportation System
NPG	NASA Procedures and Guidelines
NPR	National Procedural Requirements
NRA	NASA Research Announcement
NTX	North Texas Research Facility
PARR	Problem Analysis and Resolution Ranking
PBC	Performance-based Contract
PBS	Performance-based Services
PD	Program Director
PI	Principal Investigator
PM	Project Manager
PMT	Program Management Tool
POC	point of contact
POP	Program Operating Plan
PS	Project Scientist
RCP	required communication performance
RM	Research Manager
RNP	required navigation performance
RFA	Research Focus Area
RFI	Request for Information
RSP	Required Surveillance Performance
R&T	Research and Technology

RTA	Required Time of Arrival
RTSP	Required Total System Performance
RTT	Research Transition Teams
SA	Separation Assurance
SAA	Space Act Agreement
SAIE	Systems Analysis, Integration and Evaluation Project
SBIR	Small Business Innovative Research
SDO	Super-Density Operations
SESO	Safe and Efficient Surface Operations
SLDAST	System-level Design, Analysis and Simulation Tools
TBD	To Be Determined
TBO	Trajectory Based Operations
TFM	Traffic Flow Management
TL	Technical Lead
TP	Trajectory Prediction
TPSU	Trajectory Prediction, Synthesis and Uncertainty
TRACON	Terminal Radar Approach Control
TRL	Technology Readiness Level
URET	User Request and Evaluation Tool
WBS	Work Breakdown Structure
WebTADS	Web-based Time and Attendance System
Wx	Weather
WYE	Work Year Equivalent

Appendix O. Waivers and Deviation Log

Appendix P. Change Log

Revision	Description of Change	Responsible Author	Effective Date
1.0	Baseline Document	R.Aquilina	11/17/06
2.0	FY2008 Adjustments	M. Landis	6/26/08
3.0	FY 2009 Update. DRAFT	M. Landis	11/26/2008
4.0	FY 2010 Update, Version 3.0	R. Aquilina	5/18/2010
5.0	FY FY2011-2015 Project Plan, Version 3.0	R. Aquilina	04/05/2011