SECTION C - DESCRIPTION/SPECIFICATIONS/STATEMENT OF WORK

C.1 SPECIFICATION/STATEMENT OF WORK

The Contractor shall provide the item or services specified in Section B in accordance with the following:

Statement of Work (SOW)

Research Focus Area: System-Level Design, Analysis, and Simulation Tools (SLDAST)

Title: Advanced Concepts Evaluation System (ACES)

Date: December 18, 2008

1. INTRODUCTION

Aviation researchers and planners need a way to fully visualize and analyze the air transportation system in order to (1) examine the costs and benefits of innovative, new operational paradigms; (2) identify the most promising concepts for reducing delay, increasing capacity, and accommodating forecasted demand growth; and (3) make informed decisions early in the technology development process to inform future investment strategies and public policy formulation.

National Aeronautics and Space Administration (NASA) developed ACES in response to this need. ACES is a non-real-time, computer simulation for visualizing local, regional, and nationwide factors characterizing aircraft operations from gate departure to gate arrival. NASA's overarching objective in developing ACES is to provide a flexible simulation and modeling environment for identifying and assessing the impact of new Air Traffic Management (ATM) tools, concepts, and architectures on the National Airspace System (NAS), especially those that represent a significant departure from the existing paradigm. Its primary purpose is concept evaluation.

In keeping with this objective, ACES utilizes a distributed architecture and "agent-based" modeling to create the large-scale, distributed simulation framework necessary to support NAS-wide simulations. From a software perspective, an agent is an event-driven, persistent software entity that encapsulates the behavior of a user or other entity and interacts with other agents using a message-based communication paradigm. An agent-based modeling approach makes it possible to represent individual elements of the NAS (e.g., air traffic controllers, traffic flow managers, flights, etc.) and actions (e.g., conflict detection and resolution, arrival scheduling, etc.) and then to capture critical cascading effects across the system. More importantly, and of particular relevance to this SOW activity, agent-based modeling makes it possible to modify individual models to represent new operational concepts while minimizing development impacts on the overall simulation system.

ACES provides a common modeling approach to study alternative ways that individual elements and actions of the NAS interact with each other and exchange information over long-term strategic timeframes and SOW-term tactical timeframes. ACES also provides a way to study hierarchical interactions between NAS elements and actions relative to the ways that information and constraints are represented and used. For example, Traffic Flow Management (TFM) deals with aggregated flows of aircraft and Separation Assurance (SA) deals with very precise short-term trajectories of specific aircraft. TFM and SA need to exchange constraints and state information, but each has fundamentally different objectives and representations of aircraft state. ACES can capture these distinctions and interactions to help researchers assess integrated system-level design alternatives.

2. DURATION

ACES research, development, and support will take place over a two-year base period with three one-year options.

3. OBJECTIVE

The principal objective of this research activity is two-fold: (1) to enhance and extend the system-wide modeling and simulation capability inherent in the Airspace Concepts Evaluation System (ACES) to accommodate higher fidelity analyses of Next Generation (NextGen) ATM concepts and capabilities currently undergoing research by the NextGen Airspace and NextGen Airportal projects; and (2) to integrate ACES concepts model research and development fully across all operational concepts currently undergoing development. Example concepts include:

- TFM operational concepts
- SA operational concepts
- Dynamic Airspace Configuration (DAC) operational concepts
- Airspace Super Density Operations (ASDO) operational concepts
- Surface operational concepts studied under the Safe and Efficient Surface Operations (SESO) area

Supporting objectives are to:

- Enhance ACES flexibility, maintainability, and usability for an evolving user-base across a range of applications.
- Provide software and model verification and validation studies.
- Create new analytical output metrics.
- Create new models for TFM, SA, DAC, ASDO, and SESO.
- Integrate third-party models into ACES.
- Develop pre- and post-processing tools for ACES data.
- Develop custom models per researcher requirements.
- Transition ACES to a new architecture to support modeling evolution and decomposition commensurate with NextGen concepts, which NASA and others will pursue.
- Maintain and archive ACES software code base, including tracking and resolving bugs and documenting the tool

4. NEXT-GEN PROJECT MILESTONES

The project milestones listed here are subject to change. However the general scope of the milestones should remain. Milestone numbers and years listed are from Appendix D, 29.

- Develop interim system-level concepts of operations to accommodate 3X demand based on results of studies and identified gaps (AS.1.7.04, FY09).
- Develop method for modeling human workload in fast-time simulations, and validate models against workload measurements (AS.2.7.01, FY10).
- Conduct objective analysis of service provider and aircraft operator separation assurance methods (AS.3.7.01, FY10).
- Develop fast-time system-level simulation of NGATS technologies (AS.3.7.02, FY10).
- Develop tools for generating future demand scenarios and analyzing NGATS data (AS.3.7.03, FY10).
- Develop refined system-level concepts of operations based on results of modeling, safety, cost-benefits, and human-in-the-loop simulations (AS.4.7.01, FY11).
- Develop algorithms to generate robust optimized solutions for surface traffic planning and control (AP.2.S.03, FY09).
- Integrate and evaluate surface traffic planning algorithms/tools in fast-time simulation environment (AP.3.S.02, FY10).

- Initial validation of four-dimensional (4D) trajectory-based safe and efficient surface operation functions and procedures (AP.4.S.01, FY11).

5. BACKGROUND

The ACES user base consists of a large number of NASA researchers and developers as well as users from industry and academia, and is growing. The user base includes users that are very knowledgeable about the ACES code base and are active in its development, and those who simply use the released versions of the software. The goal of this SOW is to further develop ACES to address the needs of the evolving ACES user base and to address critical modeling needs of the Airspace Systems Program. The following sections present the ACES development history, architecture and infrastructure, air traffic management models, and future vision.

For example the ACES simulation uses data that define the simulated airports and airspace.

- The airport database contains latitude and longitude information for 2,100 domestic and international airports.

- The airspace database contains boundary information for continental US Air Route Traffic Control Center (ARTCCs) and sectors, which includes latitude and longitude values, altitude stratifications, and descriptions of terminal area airspace and airports that define the boundary around an airport and associated departure and arrival meter fixes.

This example shows that NextGen Airspace Project researchers and others need a simulation and modeling tool that can accommodate a future airspace structure that will be profoundly different from today's structure. Accordingly, ACES must represent different sector and center boundaries.

5.1 Development History

ACES has gained increased usage and acceptance among researchers, concept developers, and analysts in recent years. NASA, the Federal Aviation Administration (FAA), the Joint Planning and Development Office (JPDO), and others are currently using it to analyze initial NextGen concepts.

Previous ACES research and development laid the groundwork for modeling NAS operational concepts in gate-to-gate simulations using a mixture of NAS models with varying levels of fidelity. Today, ACES provides analysis capability using relatively high fidelity en-route airspace models and relatively low-fidelity airport surface and terminal models.

ACES development follows a periodic build cycle, with a major release every year. Each major release adds models, increases model fidelity, improves the simulation architecture, provides bug fixes, and improves usability and performance. The first major release, Build 1, was delivered to NASA in March 2003. Build 2 was delivered in October 2003, Build 3 was delivered in July 2004, Build 4 was delivered in July 2005, and Build 5 was delivered in October 2007.

[NOTE: Research and Development under this SOW will target Build 7 in 2009 and Build 8 in 2010. Future research and development beyond the scope of this SOW will target Build 9 in 2011, Build 10 in 2012, and Build 11 in 2013. This development cycle is critical to meeting NextGen Airspace Project milestone and will comprise a major part of the work under this SOW.]

Core developments over the past three years include:

- Improved plug-in architecture
- Facilitated integration of new agents and activities
- Run-time visualization implemented as a plug-in
- Multi-run, batch interface support for plug-ins
- Enabled new sector geometries and facilitated their implementation
- Read and implemented current FAA data for sector geometry
- Enhanced descent profile model for arrivals
- Updated Eurocontrol Base of Aircraft DAta (BADA) files with four new models and 27 substitutions
- Modeled international over-flights (improved sector counts)
- Enabled overlapping Terminal Radar Approach Control Centers (TRACONS) and short en-route flights
- Developed new Communication, Navigation, and Surveillance (CNS) models and improved CNS model integration
- Developed new re-routing agent with 4D polygon representation of weather obstructions
- Increased the total number of flights that the tool can simulate.

5.2 Architecture and Infrastructure

ACES is a suite of models and an infrastructure that runs the models. The models can be configured to address an ever-increasing range of concepts and evaluation criteria. This approach leverages distributed simulation capabilities and models representing key components of the air traffic system integrated into a gate-to-gate tool. The various models of ACES are shown in Figure 1 ACES Models.

The foundational core consists of models of the physics and structure of the NAS. This includes models of (1) flight physics; (2) airspace configuration (e.g., arrival/departure routes, various air traffic control (ATC) regions, etc.); (3) airport configurations (e.g., arrival/departure rates, runway configurations, and surface configurations); (4) weather and environmental factors (e.g., winds and the impact of weather on en-route and airport capacities); and (5) flight demand and schedules.

In additional to the foundational core, ACES uses a communication, observation, and data infrastructure to interact with the physical and structural models of the NAS and with other ACES command and control entities. By modeling communications and information flow, ACES makes it possible to study the dynamic interactions between agents in the NAS and to assess how local disruptions might propagate system-wide. This capability enables ACES to model alternative roles and activities for command and control agents. An important feature is the ability to represent the forecasting ability that command and control agents use to make decisions. This feature supports the development and evaluation of new decision support tools and automation functions that may comprise integral elements of the TFM, SA, DAC, and ASDO operational concepts undergoing development by the NextGen Project and which research under this SOW will support.

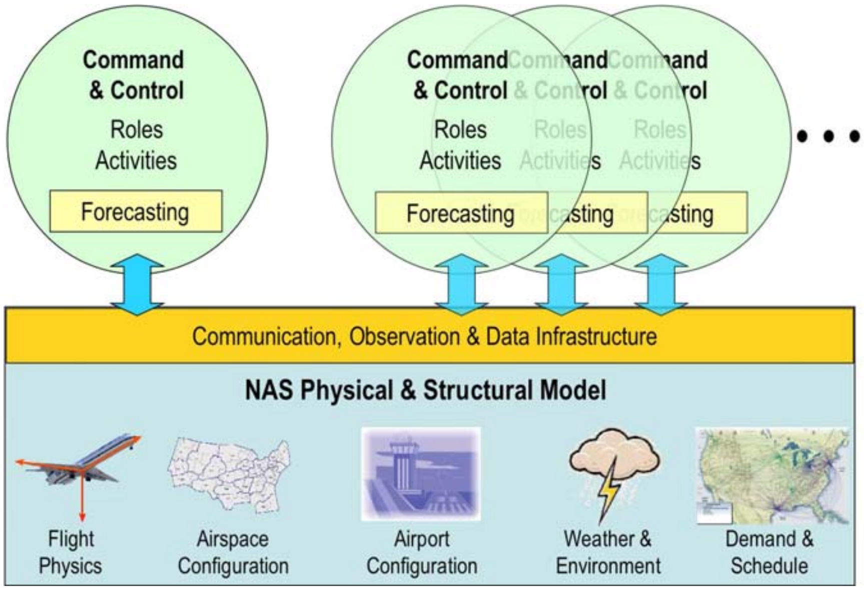

Figure 1 ACES Models

The core modeling and simulation infrastructure of ACES Build 1 through Build 3 was based on the High Level Architecture (HLA) integrated with OpenCybele from www.opencybele.org, an agent-based modeling and simulation framework. The integrated architecture provided an excellent framework for modeling and simulating the NAS with current traffic densities but was insufficient for simulating a future NAS with double or triple today's traffic densities. To address the associated memory and performance issues, NASA made the transition from the hybrid, Cybele-HLA-based framework of ACES Build 3.0 to a single CyblePro-based framework in ACES Build 4.0 and Build 5.0. CybelePro is the commercial release of an agent infrastructure developed by Intelligent Automation, Inc., that is used by government, industry, and academia for applications in modeling and simulation and development of open systems.

Figure 2 shows the ACES architecture today. At the lowest level, CybelePro provides the modeling framework and the communications, timing, and concurrency management necessary for distributed simulation. The applications layer of the architecture consists of applications built on this common core infrastructure. This includes simulation containers, as well as utilities such as simulation control, profile analysis tools, centralized logging, local data collection, message collection, and visualization.

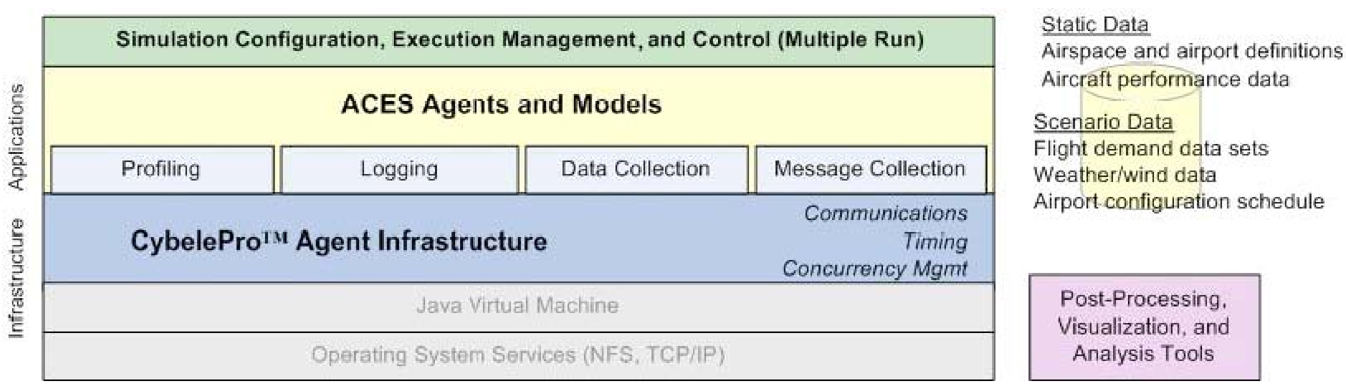

Figure 2 ACES Architecture

Simulation configuration and set-up is handled through the multiple run system, an ACES support tool that makes it possible to perform multiple simulation executions without user intervention. A user can specify the execution of a single run, or a series of runs, on a set of machines. The multiple run system has a graphical user interface that allows users to configure and schedule ACES simulation runs.

The system also contains a number of non-runtime components, shown on the right-hand side of Figure 2. These components focus on scenario generation, configuration of simulation applications, and data management and assessment tools for analyzing simulation results.

ACES can run under multiple operating systems, including Windows, Linux, and Mac OS X.

5.3 Core Model Descriptions

ACES features ATC and TFM models and models flights, airports, airspaces, and Airline Operation Centers (AOCs) operating throughout the United States. NASA and others use it to predict system delays in response to future capacity and demand scenarios and to perform benefits assessments of current and future airspace technologies and operational concepts. Such uses require a simulation architecture that supports the plug and play of different models for ATC, TFM, and AOC activity, together with multi-fidelity modeling of flights, airports, and airspaces. Appendix D, Ref. 9 provides a description of ACES core models, which represent:

- Airport TFM
- Airport ATC
- TFM in terminal airspace
- ATC in terminal airspace
- TFM in en-route airspace
- ATC in en-route airspace
- National air traffic systems command center
- AOC
- Flight physics
- 4D winds

ACES accounts for terminal gate pushback and arrival, taxiing on the ground, runway system takeoff and landing, local approach and departure, climb and descent transition, and cruise operations. ACES employs a multi-trajectory-based modeling approach that currently models TFM, ATC and flight operations, en route winds, and airport operating conditions. Software agents that exchange messages to relay information represent TFM, ATC, and flight operations. The ACES simulation applies a continual-feedback, hierarchical-modeling process to capture actions and responses among scheduling and trajectory planning, flight deck trajectory management, TFM strategic trajectory planning, and ATC tactical trajectory management operations. The intent is to describe air traffic movement resulting from the interaction of the operational and technological constructs. By this process, TFM modeling agents in ACES assess projected demand over planning horizons and issue traffic restrictions to ATC agents. ACES also simulates the propagation of TFM constraints through the NAS. ATC agents manage tactical flight movement by applying standard operating procedures, subject to the TFM restrictions.

5.4 ACES-X

Over the past three years, NASA initiated preliminary development of a new ACES architecture under the development name ACES-X. In the original ACES architecture, agents often encapsulated physical models along with command and control models. A key feature of ACES-X is to maintain a strict separation of command and control models from models of the physical and operational systems. It is hoped that this separation will speed the development of plug and play models by improving simulation composability. This would enable more rapid deployment of new models that represent potential operational concepts or provide alternative levels of fidelity.

The first phase of ACES-X development focused on prototyping physical, mechanical models such as the terminal area plant (TAP), which consists of models of airports and terminal airspaces. Each model consists of a set of nodes and links that the user connects to form a network. Nodes model runways, fixes, taxi intersections, gates, and other points of interest, while links model taxiways, departure paths, and arrival paths. Nodes can apply metering, flow distribution, and sequencing functions. Links can use different fidelities of flight transit models. The user can adjust model fidelity by changing (1) the complexity of the node-link network or (2) the way that the link models the flight transit between nodes. The ACES-X development also produced prototype plant models for the en-route plant and the flight operations plant.

A full transition to a new ACES architecture will make it easier to set up and analyze complex simulations of the NextGen concepts.

6. SOFTWARE AND MODEL DEVELOPMENT APPROACH

This SOW will focus on the system-level modeling, simulation, and analysis of future concepts of the air transportation system. Accordingly, the proposed effort will require a significant investment in models development, software infrastructure and architecture development, systems engineering, systems integration, software maintenance, documentation development, and user support for ACES models and agents. The contractor will demonstrate the capability to extend ACES modeling fidelity and improve ACES to support regional and system-wide studies of NextGen concepts undergoing development by NASA's NextGen Airspace Project and NextGen Airportal Project.

Accordingly, the contractor will demonstrate knowledge and past experience in ATM systems, research and development associated with future concepts in air transportation, and development of distributed simulation systems. The effort will employ best practices in systems engineering, software integration, software engineering, software and model verification and validation, and research analysis.

The contractor will demonstrate the ability to use Linux as the primary development platform and follow appropriate coding standards to maximize platform independence that will enable ACES to run on other platforms, including Windows and Mac OSX. NASA will consider requests to validate other operating systems.

The proposed software effort will be measurable to the extent that stakeholders (technical monitor and users/researchers) can agree when requirements have been satisfied. The contractor will work closely with NASA to interview current and potential users on how ACES is used.

Multi-Domain Expertise of Proposed Team

ACES can model, without compromising research objectives, certain domains at reasonably high fidelity while modeling other domains at low fidelity. As a research tool, ACES' effectiveness depends on the researcher's ability to determine the optimum combination of fidelity required to model particular research issues at hand, and then to verify that the resulting simulation is operationally relevant. ACES' effectiveness also depends on researchers who can combine modeling and simulation training and experience with a real world perspective. NASA's Airspace Systems Program provides much of this expertise. The contractor will demonstrate a corresponding degree of knowledge and experience with proven success in the following areas:

- Capability to manage geographically dispersed, collaborative software development with contributors from multiple organizations.
- Capability to manage dynamic requirement changes due to evolving research.
- System engineering and architectural development.
- Developing modular, plug-and-play software that integrates with legacy systems.
- Capability to produce measurable software requirements.
- Developing distributed, fast-time, event-based, agent simulation software.
- Developing large scale, maintainable, well-documented Java software.
- Developing fast/efficient and easy-to-use software.
- Providing software user and developer training.
- Executing research in ATM and aircraft simulation labs. The contractor will demonstrate a range of domain expertise in (1) ATM systems, (2) advanced distributed ATM concepts and technologies, and (3) ATM research execution.
- Developing and studying advanced, distributed ATM concepts and technologies, as well as NextGen concepts for air transportation, flight, and ATC operations relevant to NASA research objectives.
- An in-depth understanding of NextGen Airspace and Airportal Project research objectives and their application to modeling and simulation requirements associated with the analysis of TFM, SA, DAC, ASDO, and SESO concepts at levels of fidelity and accuracy appropriate to the research objectives.
- Developing experiment methodologies for simulation tools that produce results with metrics that are meaningful to the research and operational communities.

7. Tasks

As ACES has been in development for the past seven years, it has many of the models described in this statement of work. These models will require enhancement on an ongoing basis. Also ongoing are the supporting activities such as software training, maintenance, and documentation. Unless indicated otherwise, tasks are ongoing.

7.1 Base Period Tasks

The contractor shall deliver a release candidate version of ACES Build 7.0 to NASA for evaluation and testing nine months after contract award. Final delivery of ACES Build 7.1 shall be 12 months after contract award.

The contractor shall deliver a release candidate version of ACES Build 8.0 to NASA for evaluation and testing nine months after initiating the 2nd year of the base period. Final delivery of ACES Build 8.1 shall be 12 months after initiating the 2nd year of the base period.

7.2 Option Years Tasks

The contractor shall deliver a release candidate version of ACES Build 10.0 to NASA for evaluation and testing nine months after initiating the 1st option-year period. Final delivery of ACES Build 10.1 shall be 12 months after initiating the 1st option-year period.

The contractor shall deliver a release candidate version of ACES Build 11.0 to NASA for evaluation and testing nine months after initiating the 2nd option-year period. Final delivery of ACES Build 11.1 shall be 12 months after initiating the 2nd option-year period.

The contractor shall deliver a release candidate version of ACES Build 12.0 to NASA for evaluation and testing nine months after initiating the 3rd option-year period. Final delivery of ACES Build 12.1 shall be 12 months after initiating the 3rd option-year period.

7.3 ACES Task Implementation Plan (TIP) (Contract Data Requirements List (CDRL) 1)

The contractor shall develop a task implementation plan for each year of the Base Period and the three Option Periods. The schedule for delivery of the plan is 30 days after the initiation of each year of the contract. This is intended to be a living document adapting to changing requirements.

Description: The plan shall include a detailed description, schedule and breakdown by task of proposed costs for the execution of all necessary activities for the completion of the Base Period tasks of this Statement of Work. The plan shall include delivery of one or more interim builds between Builds 6 and 7 and all subsequent releases. The plan shall include a process for regular communication and collaboration with researchers and software engineers (as needed) at NASA Ames Research Center and a process for reporting of issues and progress to researchers at NASA Ames Research Center.

7.3.1 Requirements

The Task Implementation Plan shall include the following:

7.3.1.1 Define the Work Breakdown Structure (WBS) necessary to execute the tasks specified in the SOW, the associated resources, schedule and budget.

7.3.1.2 Address any known technical and cost risks appendant to the proposed approach.

7.3.1.3 Define the task and sequence of tasks that shall be performed to provide orderly technical development, design, review, interface, test and integration as required.

7.3.1.4 Provide plans, such as configuration, logistics, software, verification, integration and the appendant tests (additional details in CDRL 16 – see below).

7.3.1.5 Evaluations of the current operational concepts being developed by the NextGen Airspace Project and NextGen Airportal Project.

7.3.1.6 A review of the ACES design and architecture.

7.3.1.7 A process for establishing and maintaining regular communication and collaboration with researchers and software engineers at NASA Ames Research Center.

7.4 ACES Software and Data Management Plan (CDRL 16)

The contractor shall develop a *Software and Data Management Plan* based on NASA's ACES *Software Development and Management Plan – CDRL 16* (Appendix D, Reference 7). The contractor may specify an alternative approach provided it meets equivalent standards of quality, maintainability, and repeatability. The plan shall include NASA-approved modifications to address systems integration and engineering requirements, configuration management, bug tracking, logistics, software (including consistent directory/folder structure), verification, integration and the appendant tests. This plan shall also include data management in support of scenario data documentation and management activities (option years only). The schedule for delivery of the plan is 30 days after the contract award date.

7.5 ACES Modeling Research and Development

Description: Research performed under this SOW will focus on developing new agents, agent activities, services, and models for ACES. Research will further focus on extending the capability of existing agents and models.

ACES must accommodate a variety of models with different levels of fidelity for similar functions. The software must be relatively easy to modify for use in modeling new features and functionalities that will characterize the TFM, SA, DAC, ASDO, and SESO concepts undergoing development. Accordingly, contractors will demonstrate the capability to (1) collaborate closely with concept development teams in the NextGen Airspace and NextGen Airportal projects and (2) recommend and implement model enhancements that address key features and issues associated with each new concept.

The contractor will investigate potential modeling approaches for meeting the requirements and present the alternatives to NASA. The contractor will document any development, including an engineering design document and a software design document subject to NASA review and approval. The proposed system will be capable of modeling current day airport and airspace operations and NextGen concepts. The contractor will begin with development of the software for concepts as described in subsequent sub-sections.

Models and concepts for the following tasks may include multiple models that need to function with each other and also be integrated into the ACES tool, including interactions to other concepts and models within ACES or those connected to ACES. The contractor will develop some models, and some may be developed by NASA or other developers.

For each task, an example of models or concepts to be developed/integrated will be listed in the respective section below. The list includes expected interacting concepts or models. Special consideration for each model will also be listed.

7.5.1 Traffic Flow Management Concepts Modeling

Description:
Traffic Flow Management (TFM) is concerned with strategically scheduling and rerouting flights to strategically and equitably resolve system capacity and demand imbalances due to disturbances such as weather. TFM in ACES uses 2 to 6 hour predictions of traffic in determining courses of actions. TFM works in tandem with terminal, surface and enroute agents to safely and efficiently resolve capacity and demand imbalances. Examples of expected work in TFM are given below.

FACET-based TFM - FACET is a simulation environment developed by NASA for exploring, developing, and evaluating advanced ATM concepts. NASA wanted to harness FACET's predictive modeling and strategic planning capability to provide flow control in ACES, so it developed an air traffic flow management agent based on FACET called the FACET-TFM agent.

The FACET-TFM agent has two modes of operation: (1) a human-in-the-loop mode and (2) an automatic flow control mode. In the human-in-the-loop mode, FACET presents the user with options for controlling traffic flow; the user then selects the control action(s). In the automatic flow control mode, the user sets up the flow control objectives. The user then applies selected flow control decisions to reset the aircraft flight plans in ACES. ACES simulates the aircraft operations, "flying the flights," while maintaining separation assurance and providing overall flow control through its existing method for managing demand to meet airspace and airport capacities. Meanwhile, FACET provides strategic flow control feedback to ACES.

For details on the software design and code changes made to develop the FACET-TFM agent, see the report in Appendix D, Reference 3.

Models for arrival scheduling functionality such as TMA and McTMA - The contractor will enhance and integrate the TMA and McTMA models into future versions of ACES. The TMA model is an example of a flexible, time-based metering model for arrival scheduling. However, research under this SOW is needed to modify the TMA model to operate with future versions of ACES. The TMA model assigns scheduled times of arrival to a meter fix; it also supports “point-in-space” metering to model future concepts by first considering a set of aircraft going to a destination (e.g., an airport, TRACON, or a point-in-space), and then calculating the delay that is necessary to comply with a set of constraints (e.g., TRACON, runway, or airport acceptance rates; meter-fix or point-in-space acceptance rates; or in-trail spacing).

The TMA model closely mimics NASA’s algorithms for McTMA, a decision support tool that helps create efficient and safe arrival sequences for air traffic controllers at busy airports. Users can configure the TMA model to resemble McTMA. McTMA extends time-based metering operations beyond the terminal area to improve traffic flow at critical bottlenecks en route and on departure. It is effective in coordinating time-based metering programs among adjacent ATC facilities, even in the complex Northeast corridor of the United States. This is a necessary step toward addressing the most critical air traffic bottlenecks in the NAS. The software is driven by a powerful trajectory synthesis engine that converts radar data, flight plans, and weather information into highly accurate forecasts of air traffic congestion. TMA assists en-route traffic management coordinators and air traffic controllers in flow management planning where a single Air Route Traffic Control Center (ARTCC) is responsible for managing traffic to a terminal area.

For additional information on TMA and McTMA see Appendix D, Reference 28.

7.5.1.1 Requirements

7.5.1.1.1 Other concepts that each model or concept will interact with include one or more of the following:

- TFM (e.g., GDP, GS, MIT, TFA)
- Separation Assurance and Collision Avoidance (e.g., TSAFE, TCAS)
- DAC
- Terminal Area management (e.g., ASFO, FAST, TMA, TME, STLE)
- En Route traffic management (e.g., TMA, MCTMA)
- Communications, navigation, and surveillance (e.g., ADS-B, voice, GPS, Radar)

7.5.1.1.2 The contractor shall enhance and integrate any existing TFM models and agents and others in development into future versions of ACES. Existing TFM models and agents include the following:

- A TFM agent based on the Future ATM Concepts Evaluation Tool (FACET). The agent is called FACET-based TFM
- Models for arrival scheduling such as the Traffic Management Advisor (TMA) and the Multi-center Traffic Management Advisor (McTMA)
- The current ACES standard TFM agent

7.5.1.1.3 The contractor shall further develop ACES to allow refactoring of current TFM infrastructure to enable alternative & new TFM concepts.

7.5.1.1.4 The contractor shall integrate new models in TFM, including but not limited to the following:

- An agent that models the NextGen Airspace's future TFM concept
- Support interoperability of all TFM models (new and existing) with ACES CNS models and other agents
- New TFM models representing miles-in-trail and ground delay programs
- New agent that determines and directs TFM strategies and which has a default strategy representing current operations using miles-in-trail and ground delay programs
- New probabilistic agent that determines and directs TFM strategies
- Modify and integrate the weather models to operate with the future versions of ACES
- Incorporate ATC and TFM logic for treatment of Visual Flight Rule (VFR) General Aviation (GA) flights that models delay impacts at airports, but not in airspace
- Incorporate time-varying Monitor Alert Parameter (MAP) values in the airspace sectors
- Incorporate logic to enforce or model en route and terminal area separation requirements
- The contractor shall integrate any new and existing models with ACES CNS models and other agents.

7.5.2 Separation Assurance (SA) and Collision Avoidance Concepts Modeling

Description: SA represents one of the NextGen capabilities that will require significant research if the NAS is to increase capacity sufficiently to meet anticipated demand in the 2025 timeframe. The primary function of SA is to identify and resolve conflicts between aircraft or other obstacles such as terrain or weather. The approximate time horizon for SA is 20 minutes or less. There are two major categories of SA operational concepts being investigated in the NextGen Airspace Project: (1) the centralized, ground-based, service provider approach; and (2) the decentralized, aircraft-based approach. A centralized separation strategy represents a controller-oriented separation system generating coordinated resolution advisories and emphasizes system-level stability. The decentralized strategy represents a user-oriented separation system generating independent resolution advisories that emphasize system-level stability and aircraft-level efficiency.

An important area of study concerns the transition from a centralized system to a decentralized system. Another area concerns how autonomous and ground-controlled systems operate in a mixed environment.

The new SA paradigm must be rigorously tested to demonstrate that it can perform safely given the uncertainties present within the NextGen environment. SA functionality must be further tested to determine if it can gracefully handle system failures by degrading safely. SA concepts must also seamlessly integrate with other functions that will characterize NextGen, such as TFM, DAC, and ASDO.

SA concepts may include multiple models that need to function with each other and also be integrated into the ACES tool, including interactions to other concepts and models. The contractor will develop some models, and some may be developed by NASA or other developers.

Other concepts that the SA concept will interact with include one or more of the following:

- Collision avoidance (e.g., TSAFE, TCAS)
- Terminal Area management (e.g., ASFO, FAST, TMA, TME, STLE)
- En Route traffic management (e.g., TMA, MCTMA}
- DAC
- TFM (e.g., GDP, GS, MIT, TFA)
- Communications, navigation, and surveillance (ADS-B, voice, GPS, Radar)

7.5.2.1 Requirements

7.5.2.1.1 The contractor shall maintain and upgrade existing SA models

7.5.2.1.2 The contractor shall integrate new SA models with ACES and the other concepts

7.5.2.1.3 The contractor shall develop new models in response to researcher requirements for integration into ACES.

7.5.3 Dynamic Airspace Configuration (DAC) Concepts Modeling

Description: The DAC concept of operations calls for increasing airspace capacity through dynamic allocation of airspace structure and controller resources. Designed to work in tandem with TFM to resolve demand-capacity imbalances safely and equitably, DAC will squeeze as much capacity from the airspace as possible while TFM manages demand. There are three core research areas associated with DAC: (1) overall classification and organization of airspace; (2) dynamic airspace configuration adaptations; and (3) generic airspace.

In classification and organization, the airspace may be divided into four primary regions: (1) airspace for automated SA operations; (2) high altitude airspace; (3) super density and multiple airport airspace (metroplex) operations; and (4) remaining airspace. Should all aircraft become capable of automated separation and spacing assurance under NextGen (either via ground-based or airborne based-technologies), the airspace design may be further simplified so that only arrival-departure corridors are necessary and the remaining airspace can be designated as generic airspace that will require little structure.

However, many research issues must be addressed to test the feasibility of mid- and long-term DAC concepts. Analysis is also needed to assess the benefits of DAC concepts. DAC concepts must also integrate seamlessly with other functions that will characterize NextGen, including TFM, SA, and ASDO. For detailed information on the DAC operational concept in development, see Appendix D, Reference 1.

Based on the current understanding, it appears that new airspace classes may include dynamic sectors, gaggles, platoons, and corridors in the sky. Each class has specific requirements for the traffic using its airspace, such as:

- Equipage. Automated SA Airspace (Exclusionary) will require flights utilizing its airspace to be equipped for automated separation assurance. Some tubes may require this as well. Automated SA Airspace (non-exclusionary) may allow non-equipped flights in its airspace, but to a certain capacity separate from the capacity for equipped flights or to certain percentages. Super Density and Metroplex areas will require certain Reduced Vertical Separation Minimum (RVSM) capabilities to fly Area Navigation (RNAV) routes.

- Flow or formation conformance. The tube concept is similar to freeways in the sky. This concept requires that all flights utilizing a tube are following a specific flow along one of the tube lanes. Flights in airspace surrounding the tube may not pass through the tube if they are not a part of the tube stream. They must treat the tube as an obstacle and reroute around it. Gaggles may be clusters of priority flights traveling together. The airspace that travels along with these flights would also be treated as an obstacle for flights not a part of the gaggle in surrounding airspace to avoid.
- Entrance/exit criteria. Rules for flights transitioning between airspace classes are still unclear. Tubes may be completely permeable with rules like enter from below and exit above or a tube definition may include a limited specified number of entrance or exit nodes (on and off ramps). The criteria for entering and exiting automated SA airspace may be similar or there may be tubes that serve to transition flight to and from this airspace.

7.5.3.1 Requirements

7.5.3.1.1 The contractor shall enable changes to airspace configurations based on designs, algorithms, and procedures developed under NASA's DAC research. To support near-term through far-term research, three types of DAC simulations, with progressively more challenging implementations, are required. These are: Single Day DAC concepts where a pre-specified airspace design is in place for the entire ACES runs. Scripted Dynamic DAC concepts where the ACES Scenario Manager is used to specify time or conditions when several pre-specified airspace designs are in effect during an ACES run. Run-Time Dynamic DAC concepts where agents in the ACES simulation dynamically monitor forecasted conditions and change the airspace design based on a particular DAC concept.

7.5.3.1.1.1 Single Day DAC concept models may include configurations where flights are segregated by equipage and class or where some flights are designated to fly in tubes and others are required to avoid tubes.

7.5.3.1.1.2 Scripted Dynamic DAC concept models would extend the Single Day DAC concept models to respond to scripted changes in the airspace design within an ACES run.

7.5.3.1.1.3 Run-Time Dynamic DAC concept models would implement airspace changes during run-time using algorithms and procedures developed by DAC researchers. These algorithms could be implemented external to ACES (e.g., MATLAB scripts/programs) and called by ACES or implemented within ACES. To support run-time concepts, additional models may need to be developed. These include: A model to estimate sector capacities based on trajectory predictions, weather predictions and user specified capacity metrics; a sector reconfiguration model that uses estimated traffic, weather and capacity to reassign airspace regions to different sectors; and a model to represent alternative tube concepts.

7.5.3.1.2 The contractor shall support interaction with weather models and CNS models.

7.5.3.1.3 The contractor shall ensure that DAC models interface with SA, TFM, PBS, ASDO and Terminal Area models as required for concept studies.

7.5.4 Airspace Super Density Operation (ASDO) Concepts Modeling

Description: ASDO concepts seek to improve operations in a uniquely constrained and complex airspace domain at, and near, major airports and in terminal area airspace. This airspace differs from other domains because of the density of the aircraft, the complexity of operations, the relative immaturity of research to date in this area, the inability to avoid weather without significantly disrupting traffic patterns, and environmental considerations such as noise and pollution, which are not as constraining in the en-route domain. ASDO research must effectively mesh with surface and en-route concepts in order to contribute to an integrated and coordinated view of future operations. ASDO concepts modeling in ACES will comprise an important element of this research.

The contractor will support ASDO concept development and research in ACES. This may include development and integration of new models to represent ASDO concepts, and/or integration of models developed by NASA or other researchers and users. Integration includes interfacing the models with other ASDO models, with the ACES tool, and with other NextGen concepts and models represented in ACES. For additional information on the initial ASDO concept, see Appendix D, Reference 4.

ASDO research touches on two areas, airport surface operations modeling, and terminal area airspace and operations modeling

7.5.4.1 Surface Area

Description: The Surface Traffic Limitations Enhancements (STLE) model, which is currently under development, simulates terminal gate, ramp, taxiway, and runway operations. STLE provides higher fidelity modeling of airport operations than has been available in ACES. The improved fidelity of ground operations in this model better supports research on current and future airport operational concepts, and improves the sensitivity of ACES modeling in all domains. The STLE model must simulate current day and highly automated operations.

The STLE model allows modeling of alternative surface configurations (e.g., taxiway and runway reconfiguration) and alternate operating procedures, simulates interactions between the flight deck and the AOC, and models future changes to the CNS systems. For further information on the STLE model see Appendix D, Reference 5.

Other surface modeling requirements anticipated during the course of the contract would include the following capabilities.

- A surface optimization model to output timed (4-D) taxi clearances used to control surface traffic. These 4-D clearances will orchestrate taxiing to reduce taxi times and improve surface efficiency and safety.
- Scripted airport re-configurations during a run (information about these changes would be passed to terminal-area agents and models).
- Taxi conformance monitoring and conflict detection for surface and low altitude traffic.
- Enhancing the airport model to incorporate airspace changes initiated by the DAC model during a run.
- Develop a trajectory-based surface traffic model to enable dynamic, on-the-fly routing of surface traffic.
- Model dynamically assigned runways, taxiways, and airport configurations.
- Integrated departure/arrival/surface operations.

Models would incorporate stochastic taxi times by specifying a mean, variance, and distribution type such as truncated normal, triangular, or empirical.

Additional surface concepts to be studied/modeled may be developed by the Safe and Efficient Surface Operations (SESO) research focus area. See Appendix D, Reference 27 for concepts and modeling related to SESO. As these concepts are developed they may be modeled and researched using ACES.

7.5.4.2 Terminal Area

The contractor will develop the capability to use terminal-area, node-link structures to represent transition times and fix constraints for proposed terminal-area operations. Associated ACES TFM and ATC models and agents will utilize the transition times, runway spacing constraints, and fix constraints to determine delays and adjust the routing of flights. Routing choices must include changes to runway assignment, arrival/departure meter fix assignment, and information on available terminal area trajectories for different aircraft classes and airport configurations. Consideration of gate and ramp assignment must also be included.

The new 4D terminal area model must include modeling of environmental impact, physical scheduling, and conflict constraints, implementations of specific traffic control algorithms, and the ability to interface these algorithms with surface and en-route traffic control algorithms. The contractor must ensure that the model supports CNS uncertainty, constraints for terminal-area operations, and terminal area airspace adaptations. The contractor must consider using and/or adapting existing NASA-furnished trajectory generators.

The contractor will also integrate and enhance terminal area models developed for Terminal Model Enhancement (TME) under a separate contract with NASA. Examples include modeling of side-by-side landings on closely spaced parallel runways, models for dense operations in multi-airport airspace, conflict detection and resolution (CD&R) models, dynamic weather modeling and weather avoidance algorithms, and a concept for departures from very closely spaced runways.

There may be new requirements for modeling terminal area operations that are still to be determined beyond the current TME development. These new requirements may include explicit modeling of 4D aircraft trajectories and modeling of aircraft performance limitations. It is expected that a new 4D terminal area model will be developed for ACES during the contract period.

7.5.4.3 Requirements

7.5.4.3.1 The contractor shall maintain and upgrade existing models that contribute to ASDO and SESO research.

7.5.4.3.2 The contractor shall integrate new ASDO and SESO models with ACES and with other concepts.

7.5.4.3.3 The contractor shall develop models for integrated arrival/departure/surface operations.

7.5.4.3.4 The contractor shall develop new models in response to researcher requirements for integration into ACES.

7.5.5 Trajectory Prediction, Synthesis, and Uncertainty (TPSU) Concepts Modeling

Description: Trajectory Prediction, Synthesis and Uncertainty research will provide common trajectory prediction algorithms and components, and trajectory modeling and synthesis technologies to other focus areas. These tools are needed for cutting edge research in ATM.

The contractor must develop a trajectory generator interface in ACES that allows researchers to use different trajectory generators for different research objectives. ACES must support two trajectory generators simultaneously – one to simulate true aircraft positions and one to simulate aircraft positions as seen by the controllers and automation tools, which will contain variable levels of uncertainty. The contractor will (if needed) develop a modular trajectory generator for use in ACES. The contractor will design and implement a mechanism to inject uncertainty into trajectories. The trajectory generator must generate tracks for aircraft during all phases of flight, including climb and descent.

The current TFM model only allows aircraft to slow down to meet trajectory constraints. The contractor must add functionality to TFM to allow aircraft to speed up as well to meet trajectory constraints generated by a concept.

7.5.5.1 Requirements

7.5.5.1.1 The contractor shall maintain and upgrade existing models that contribute to TPSU research.

7.5.5.1.2 The contractor shall integrate new TPSU models with ACES and with other concepts.

7.5.5.1.3 The contractor shall develop new models in response to researcher requirements for integration into ACES.

7.5.6 Performance Based Services (PBS) Concepts Modeling

Performance Based Services (PBS) is a concept where aircraft with equipment that enables more efficient airspace operations can be identified and incorporated into high efficiency operations that provide benefits to both the system and the aircraft operator. Some proposed equipage designations are Required Navigation Performance (RNP), Required Communication Performance (RCP), Required Surveillance Requirement (RSP), and Required Total System Performance (RTSP). Equipage designations might also be based on the requirements of specific ATM concepts such as AAC and 4-D ASAS (i.e., aircraft equipped for AAC and 4-D ASAS may be handled differently from each other and from unequipped aircraft).

7.5.6.1 Requirements

7.5.6.1.1 The contractor shall design and implement equipage models to support RNP including conformance monitoring, RCP, RSP, and RTSP. The flexibility to include user specified designations, such as AAC and 4-D ASAS, shall be accommodated.

7.5.6.1.2 The contractor shall integrate PBS equipage models with the ACES CNS and TPSU models as needed. Augmentation and extension of the CNS models may be necessary.

7.5.6.1.3 The contractor shall ensure that PBS equipage models interface with SA, TFM, DAC, ASDO and Terminal Area models as required for concept studies.

7.5.6.1.4 The contractor shall develop new models in response to researcher requirements for integration into ACES.

7.5.7 Enhanced Weather Modeling

Description

The Weather agent in ACES needs to be enhanced to include at least the following: true and forecasted wind, true and forecasted reflectivity and turbulence, airport lightning, and en route icing. The following three other factors need to be considered in the enhancement.

7.5.7.1 Impact of weather on available airspace

ACES must allow rerouting around weather within a sector. An option is to produce a grid level representation of weather. This design will include a means of setting sector capacity constraints based on the availability of conflict free routes through or around weather systems impacting a sector.

7.5.7.2 Airport weather effects on surface

When the precipitation map indicates any level of precipitation (rain or snow), the airport runways will be considered wet, and the AAR will be reduced accordingly. Note that this is not the same as a convective weather map that is determined by a certain level (dBZ) of precipitation that indicates hazardous weather. Surface weather impacts runway traction restrictions (wetness, snow or ice,) runway wind restrictions, and visibility restrictions (fog.) For traction, any level of precipitation is sufficient to trigger the condition of the runways to be considered slick. The precipitation input will dictate the AAR given a particular runway configuration. Prevailing winds may restrict usage of runways and require alternative runway configurations. Visibility restrictions may restrict usage of closely-space parallel runways. A table lookup chart is required to identify the relationship between the wet condition and configuration / AAR. Use of parallel runways is a function of Runway Visual Range (RVR), wind speed and direction, and ceiling data. The AAR table will implicitly account for the use (non-use) of parallel runways and configuration changes due to wind.

7.5.7.3 Weather Forecast Uncertainty

Convective weather predictions will enable long-term weather prediction (2-6 hour look ahead) as well as tactical weather situations (0-2 hour look ahead). The weather forecast model for convective weather predictions will include parameters for controlling the accuracy of the spatial and temporal location of the predicted weather as a function of look-ahead time.

A surface weather forecast model gives forecasts of when AAR are expected to change. The model should provide forecast probabilities if requested (i.e., a 50% probability of switching from IFC to VFC for SFO at 10:00AM due to fog lifting).

7.5.7.4 Requirements

7.5.7.4.1 The weather agent shall provide the ability to provide forecasted weather information to other agents requiring this type of information for planning.

7.5.7.4.2 The weather agent shall provide the ability to provide “true” weather that varies appropriately from forecasted. (The rerouting model may also require additional enhancements to take advantage of this capability.)

7.5.7.4.3 The contractor shall provide a mapping function in ACES to correlate the presence of convective weather (as per radar or other sources) with its impact on the capacity of sectors and of airports.

7.5.7.4.4 The contractor shall modify and extend ACES to make sector capacity limits a variable that can be changed during the course of a simulation as a function of a weather prediction, aircraft type, or any logic implemented by an ACES sector capacity limit agent.

7.5.7.4.5 ACES shall be able to provide weather predictions (with 30 minute default, simulated look ahead times) that could be used by user-defined agents that estimate the expected airspace throughput subject to the weather constraints.

7.5.7.4.6 The contractor shall develop a model to capture the effects of weather on airport surface operations.

7.5.7.4.7 The model shall represent the relationship between weather state variables and the effects of these variables on the Airport Acceptance Rate (AAR).

7.5.7.4.8 The contractor shall include wind shear and microburst alerts in the surface model that require the immediate closing of a runway.

7.5.7.4.9 The model shall support variable look-ahead warning times for wind shear and microburst alerts, such as 0 – 5 min look-ahead warning times to represent current warning times, and 10 – 15 min. look-ahead warning times for future warning systems. The look-ahead warning times will be implemented as user-specified variables.

7.5.7.4.10 The contractor shall enhance ACES to enable modeling of aircraft missed approaches that are a consequence of runways being closed due to wind shear and microburst alerts.

7.5.7.4.11 The contractor shall also enhance ACES to model the closing of a metering fix due to long duration of the wind shear and microburst alerts.

7.5.7.4.12 The contractor shall provide a wind forecast model and a weather forecast model in ACES for predicting convective weather.

7.5.7.4.13 The contractor shall develop new models in response to researcher requirements for integration into ACES.

7.5.8 Enhanced Mobile Resource Tracking and Scheduling

Description: ACES currently has the ability to track aircraft by their tail numbers and can model the impact that late arriving flights have on the schedule on subsequent flights using the same aircraft. It is desired to enhance ACES capabilities to include the tracking and scheduling of other mobile “resources” such as passengers, cargo and flight crews. One of the concerns is the level at which delay begins to affect passenger and cargo connections into and out of large airline hubs. Modeling of constraints on the ability of airlines to substitute equipment and crew on delayed or cancelled flights is also desired.

7.5.8.1 Requirements

7.5.8.1.1 The contractor shall develop agent-based fleet management activities for an AOC model that will enable the management and tracking of passengers, cargo, aircraft, and equipage. The fleet management activities shall be extensible to enable eventual management and tracking of flight crews, service equipment, and other objects and resources, including the management and tracking of cargo transportation on dedicated cargo flights and in the belly of passenger flights.

7.5.8.1.2 The contractor shall enhance the model to manage and track cargo transportation on dedicated cargo flights and in the belly of passenger flights.

7.5.8.1.3 The contractor shall enhance the model to track and manage the operating fleet inventory and fleet mix.

7.5.8.1.4 The contractor shall provide an AOC function for adjusting aircraft departure schedules based on the state of the traffic that allows the delay of departures as a result of delayed arrivals.

7.5.8.1.5 The contractor shall provide metrics for passenger and cargo impacts. A default set of cost metrics for airlines shall also be provided. (These may later need to be customized for alternative airline business models.)

7.5.8.1.6 The contractor shall integrate the resource tracking models with the ACES AOC and TFM models as needed.

7.5.8.1.7 The contractor shall ensure that resource tracking models interface with SA, TFM, DAC, ASDO and Terminal Area models as required for concept studies.

7.5.8.1.8 The contractor shall develop new models in response to researcher requirements for integration into ACES.

7.6 ACES Systems Engineering and Integration

Research will involve professional simulation software research and development. Accordingly, the contractor shall use best practices and standards for systems engineering, systems integration, and software maintenance as specified in *NASA's ACES Software Development and Management Plan – Contract Data Requirements List (CDRL) 16* and the review process described in the *ACES Process Bulletin 004: Software Review Process.* The contractor may develop and use an alternative plan if the plan meets equivalent standards of quality, maintainability, and repeatability. The proposal shall further support efforts associated with related work conducted by NASA and its contractors.

7.6.1 Systems Engineering Services

The contractor shall provide systems engineering services for ACES development. The contractor shall designate (1) a team member to consider and maintain a systems view of both engineering and software designs and (2) a systems engineering group to support development efforts associated with – but not limited to -- TFM, SA, DAC, ASDO, and SESO modeling research and development performed by NASA and its contractors.

7.6.2 Software Integration

The contractor shall provide software integration services for ACES development and support other development efforts associated with this research activity. The contractor shall designate one to two persons full-time, on-site, as the software integration lead to integrate software in the ACES Modeling Laboratory at NASA Ames Research Center.

The contractor will provide support that includes, but are not limited to, the following:

- Installation of software builds and hardware into the primary research facility, the ACES Laboratory.
- Technical support to isolate and resolve ACES issues.
- Instruction and operating procedures to NASA personnel on the operation of laboratory software (ACES and any other needed software) sufficient to allow NASA personnel to operate the laboratory software without assistance from the software development team.
- Technical support to isolate and resolve any issues for all system software under configuration management.
- Assisting users to configure, submit, and monitor experiment runs; archive and distribute experiment results; and run integration, verification and validation tests.

7.6.3 Software Maintenance

The contractor shall (1) provide software maintenance and help-desk services during normal business hours for ACES development; (2) utilize and support the ACES bug-tracking database maintained at NASA Ames Research Center; (3) develop and integrate bug fixes; and (4) coordinate software maintenance with other activities performed by NASA and other supporting organizations.

7.6.4 Software Engineering

7.6.4.1 Description

According to NASA Procedural Requirements (NPR) 7150.2 (http://nodis3.gsfc.nasa.gov/), all activities related to researching and developing ATM simulation tools and software are classified as Class D Analysis and Distribution Software or Class E Development Support Software, as discussed below:

Class D Analysis and Distribution Software – Non-space flight software. Software developed to perform science data collection, storage, and distribution; or perform engineering and hardware data analysis. Examples of Class D software include, but are not limited to, software tools, analysis tools, and science data collection and distribution systems.

Class E Development Support Software – Non-space flight software. Software developed to explore a design concept; or support software or hardware development functions such as requirements management, design, test, and integration, configuration management, documentation, or perform science analysis. Examples of Class E software include, but are not limited to, earth science modeling, information only websites (non- business/information technology), science data analysis, and low technology-readiness-level research software.

A defect in Class D or Class E software may cause rework but has no direct impact on mission objectives or system safety.

NPR 7150.2 does not require a Capability Maturity Model Integration – Systems Engineering/Software Engineering (CMMI®-SE/SW) capability level or maturity level for non-space flight, software activities. However, it is preferred that the software development and integration organization(s) have been successfully appraised at CMMI®-SE/SW Capability Level 2 or higher as measured by a Software Engineering Institute authorized lead appraiser from an external organization in the maturity level 2 process areas as follows:

- Requirements management
- Configuration management
- Process and product quality assurance
- Measurement and analysis
- Project planning
- Project monitoring and control
- Supplier agreement management

In lieu of a CMMI certification by a developer, the project may conduct a software capability evaluation for risk mitigation if necessary.

NPR 7150.2 should be used as a guide for specifying requirements for software management, software engineering (requirements, design, implementation, testing, etc.) and software documentation at a level appropriate to the project needs and software classification.

Contractors will provide all developed software (including source) to the Government for unrestricted Government use and duplication. NASA may approve limited exceptions if benefit to the project can be justified.

The contractor shall provide data requisite for analysis and debugging in an output format consistent with current analysis and debugging tools.

7.6.4.2 <u>Requirements</u>

7.6.4.2.1 The contractor shall provide collaborative configuration management, including tools. Open-source tools are preferred. A tool more modern than the currently used CVS is desired.

7.6.4.2.2 Process and product quality assurance. The contractor shall perform quality assurance throughout the whole development cycle: from requirements gathering to software delivery. Requirements will be measurable. Analysis will be performed.

7.6.4.2.3 Project planning

7.6.4.2.4 Project monitoring and control. The contractor shall provide collaborative monitoring management, including tools.

7.6.4.2.5 Supplier agreement management

7.6.4.2.6 The contractor shall provide all developed software (including source) to the Government for unrestricted Government use and duplication. NASA may approve limited exceptions if benefit to the project can be justified.

7.7 User Support Services and Documentation

7.7.1 Maintenance and Support

The contractor will provide maintenance and support services focused on ensuring that ACES functions properly and is usable by the aviation research community. Accordingly, The contractor will provide maintenance and support services for current ACES releases and all subsequent releases. NASA will determine when a build no longer requires maintenance and support. The contractor will support no more than two releases at any given time.

7.7.1.1 Requirements

7.7.1.1.1 Engineering and software design and development to repair and integrate critical bugs and coordinate software maintenance with other efforts performed by NASA and other organizations.

7.7.1.1.2 An ACES bug-tracking database maintained by the contractor at NASA Ames Research Center.

7.7.2 Other User Support Services

7.7.2.1 Requirements

7.7.2.1.1 The contractor shall participate in no more than two brainstorming workshops at NASA Ames Research Center in the first year of the base period to discuss NextGen concepts modeling requirements and ACES capabilities essential to meeting those requirements.

7.7.2.1.2 The contractor shall further specify support for up to two technical briefing meetings per year at NASA Ames Research Center. Support will include the preparation of meeting materials and the dissemination of information and advice to workshop and meeting attendees engaged in developing ACES models and software.

7.7.2.1.3 The contractor shall further maintain and staff a user support system for the ACES user community and specify support services that will be provided. Support will accommodate initial contact from users via a centralized online database, email, or telephone. The contractor will respond by the end of the next business day. It is anticipated that an average of 5 to 10 user support requests may be received each week.

7.7.2.1.4 The contractor shall automate the user-support database.

7.7.2.1.5 The contractor shall provide a comprehensive, systematic tutorial that illustrates how to run a sample test case (i.e., from initiating a simulation to extracting data from the database) and specify support services that will provided. The contractor will utilize Government-Furnished-Information (i.e., NASA-supplied software and engineering design documents) when NASA considers it necessary to do so.

7.7.2.1.6 Contractors shall participate in ACES development teleconferences.

7.7.3 Documentation Support

The contractor will provide documentation support throughout the contract period.

7.7.3.1 <u>Requirements</u>

7.7.3.1.1 Document researcher use cases.

7.7.3.1.2 Identify and define the support services that will be provided.

7.7.3.1.3 Specify that documentation will be provided in each build as a comprehensive, integrated, self-contained up-to-date on-line electronic format that is accessible from a single location, such as in an application help system.

7.7.3.1.4 Specify the use of best practices used in software system documentation and on-line help utilities. Documentation shall include appropriate linking of topics, search capabilities, and other functions as defined by best practices and standards.

7.7.3.1.5 Specify that the documentation will be viewable by readily available applications on Windows, Linux, and Mac OS X operating systems.

7.7.3.1.6 Documentation shall incorporate information developed in support of other research and development performed under this SOW as deemed necessary by the Government.

7.7.3.1.7 The contractor shall obtain Government acceptance of all documentation and provide review drafts of each document no later than 30 days prior to final delivery. The Government will provide feedback on the documents no later than 15 days prior to the required delivery date.

7.7.3.2 <u>Software and System Documentation</u>

The contractor will review and revise existing ACES software and system documentation to insure that the content is up to date, accurate, and fully captures all aspects of the system for both the user and developer.

ACES Top Level Modeling System Requirements Document – This document will provide a summary of ACES functional capabilities.

ACES User Guide and Tutorial – This document will provide ACES users and administrators with detailed examples of installing and using ACES, including input configuration and output interpretation. The contractor may specify use of the existing *ACES Users Guide* as a baseline document.

ACES Programmers Guide – This document will specify a process and plan to guide users in writing and modifying agents, activities, and functions associated with ACES software and models. This document will further support plug-and-play development in the ACES architecture and will include a comprehensive description of ACES application program interfaces. This document will also specify support for documenting public-access code (including expected input and example, and return value and type) in javadoc style and include detailed programming examples.

ACES Software Design Documentation – This documentation will describe the functional capabilities, limitations, performance, design constraints, and system interfaces for the ACES modeling system and its subsystems as well as the specifications for the data exchange interface between models used in ACES simulations. The documentation will further include as a minimum:

- Top level view of software system, including its relationship to existing subsystem
- Model and architecture system/subsystem specifications
- Engineering design documentation
- Software design documentation
- Model interface control documentation

ACES Test and Verification Documentation – This documentation will describe a process for the testing and verification of the ACES modeling system and its subsystems and will include as a minimum:

- System test descriptions
- Input and output files for all tests
- *System Test and Verification Report*

ACES Capabilities Document – This document will list ACES functional capabilities from a researcher point of view, without the requirement wording as in *ACES Top Level Modeling System Requirements Document.* The former will be done towards the completion of development based on the latter, which will be done at the beginning of development.

ACES Traceability Matrix – This document will trace design, test plan, and test cases to use cases and requirements.

ACES Use Cases – This document will cover researchers' perspectives, not user interface's perspectives.

ACES Data Model/Schema – This documentation will include as a minimum:

Schema Diagram that shows any relational database table relationship, including keys mapping from table to table.

ACES Scenario Data Management and Documentation -- The contractor will document the origins, reliability, and limitations of new datasets used to generate ACES scenarios. The contractor will also specify a procedure to break apart, organize, document, and manage ACES input data. The contractor will specify use of the ACES bug-tracking database at NASA Ames Research Center to report and fix new issues concerning current datasets and to integrate data corrections and modifications. The contractor will identify data sources, procedures, and software tools for processing and testing new data sets; utilize Government-Furnished-Information (i.e., software and engineering design documents) when NASA considers it necessary; and coordinate scenario data documentation and management with related work performed by NASA and others under this research activity.

The contractor will generate a report describing and summarizing the scenario analysis specified in Section 7.9. The report will include a gap analysis that identifies capabilities that would improve the ability to model and evaluate the specified scenario.

7.7.3.2.1 <u>Requirements</u>

The contractor shall provide documentation support for the following:

7.7.3.2.1.1 ACES Top Level Modeling System Requirements Document (CDRL 10)

7.7.3.2.1.2 ACES User Guide and Tutorial (CDRL 17, described below)

7.7.3.2.1.3 ACES Programmers Guide (CDRL 18, described below)

7.7.3.2.1.4 ACES Software Design Document (CDRL 19, described below)

7.7.3.2.1.5 ACES Test and Verification Documentation (CDRL 20, described below)

7.7.3.2.1.6 ACES Capabilities Document (CDRL 29, described below)

7.7.3.2.1.7 ACES Traceability Matrix (CDRL 30, for new development)

7.7.3.2.1.8 ACES Use Cases (CDRL 31, for new development)

7.7.3.2.1.9 ACES Data Model/Schema (CDRL 32, described below)

7.7.3.2.1.10 ACES Scenario Data Management and Documentation (CDRL 26)

7.7.3.2.1.11 The contractor shall deliver electronic copies of documentations, together with all configurations and scenario data, ACES input data, and relevant analysis data.

7.7.3.2.1.12 The contractor shall deliver electronic copies of documentations, together with all source code for all scripts and software developed for analysis.

7.8 ACES Infrastructure and Architecture Development

7.8.1 Usability Improvements

The contractor will interview users, propose, and develop modifications and additions to the ACES software, tools and documentation, to improve usability. The contractor will (1) improve ACES user interface and (2) design, develop, and maintain a suite of utilities that create, modify, and manage input, run-time, and output data in order to simplify the user's interaction with ACES. The utilities shall run in the ACES environment and include the following:

- Integration with ACESViewer
- Development of a full run summary log and report
- Extension and enhancement of the current scenario manager
- Review and maintenance of coding standards to ensure code portability across operating systems
- Support for visual analysis tool development
- Extension and enhancement of database usage
- eXtensible Markup Language (XML) data management

7.8.1.1 <u>Requirements</u>

The contractor shall provide usability improvements from the following list:

7.8.1.1.1 Allow efficient regional studies. A candidate is to allow starting of ACES from the middle of a previous run. For studies that focus on a region, the current ACES would still run with the rest of the NAS traffic from beginning to end. This full run is longer in simulation time than necessary.

7.8.1.1.2 Streamline software distribution such that big data sets are not duplicated in storage. For example, the same Rapid Update Cycle (RUC) data is stored with each version of ACES and there are many versions (main plus variations) end up being created in development and during research.

7.8.1.1.3 Enhance the current scenario manager by enabling the use of additional messages, triggering events, and triggering logic. The long-term goal is that any message produced within ACES can be used as an input to the scenario manager.

7.8.1.1.4 Define and put into place a process that will make it easier for researchers to hand-off ACES issues and problems to an investigative team whose responsibility would be to gather the necessary information needed by developers to evaluate and correct issues and problems.

7.8.1.1.5 Provide resources as necessary to support NASA's development of visual analysis tools.

7.8.1.1.6 Support the extension and enhancement of database use within ACES.

7.8.1.1.7 Develop interfaces and utilities to make the creation, modification, and maintenance of XML data sources easier.

7.8.1.1.8 Improve and extend post-processed metrics calculations within ACES used to evaluate the needs and requirements associated with run-time metrics calculations. The performer may use run-time metrics as triggering devices for the user. NASA will provide an initial list of applicable metrics for this task upon request.

7.8.1.1.9 Streamline the organization of the build tree and build scripts for ease-of-use in an Integrated Development Environment (IDE) such as Eclipse, an open-source software framework written primarily in Java. Provide debugging capability using Eclipse-like utilities)

7.8.1.1.10 Provide a mechanism for allowing any input and configuration to be captured as part of a simulation result, including code modification for repeatability and verification purposes.

7.8.1.1.11 Enhance and extend development of existing utilities and prototypes to function as part of an enhanced ACES toolbox.

7.8.1.1.12 Standardize location of each software component.

7.8.1.1.13 Provide location of each software component in a diagram/map.

7.8.1.1.14 Improve the ACES user interface. Enhance and extend ACES features and functions, including the following:

- Allow the user to easily re-run a group of tests, select a number of configurations and combine them into a single run group. It shall allow running the list of jobs in the group in the order listed. For reporting purposes, the results shall be retrievable by the group. The contractor shall work with NASA to define the interface.

- Any list shall be selectable for more than one item at a time.

- Any list on ACES graphical user interface shall be sortable by time of creation or alphabetically.

- An old item shall not be listed after a newer item in a job list.

7.8.1.1.15 Effective utilization of multi-core CPU, 64bit architecture, and multi-threaded hardware and software.

7.8.1.1.16 Effective utilization of multiple machine configurations; i.e., the capability to run on N number of machines that would result in optimal run-time performance. The capability shall address network bandwidth and latency, overhead, messaging, memory, heap size, disk utilization, scalability, maintaining repeatability of results across alternate machines and Java Virtual Machines/Generic Masters configurations.

7.8.1.1.17 User guideline for simulation configuration to best utilize the multiple machines, multi-core CPU, 64bit architecture, and multi-thread architecture for different classes of simulations such as CNS modeling, high-fidelity separation assurance modeling, and regional vs. system-wide simulations. The guideline shall address network bandwidth and latency, overhead, messaging, memory, heap size, disk utilization, scalability, maintaining repeatability of results across alternate machines and Java Virtual Machines/Generic Masters configurations.

7.8.1.1.18 New usability improvements identified by NASA or contractor.

7.8.2 Development of System-Level Design and Architecture

The contractor shall establish a system-level design and architecture development team to evaluate the current concepts and review existing ACES designs and architectures. The contractor shall further define the requirements for developing a system-level design and architecture for future versions of ACES. The contractor shall review existing software components and frameworks, and make recommendations for consolidations or replacements.

The contractor shall designate at least a full-time, appropriately qualified system software architect to lead the system-level design and architecture development team. The size of the team will be at the discretion of the contractor but shall be adequate to support the research activity. The contractor shall further produce a requirements document and a system-level design with supporting documentation and present the proposed design and architecture to NASA for review and feedback. The contractor shall create, document, maintain, and modify a requirements list, system-level design, and architecture as development efforts move forward. The contractor shall specify the use of a lead architect to define a development strategy, development plan, and a schedule, who would then manage the technical development to maintain alignment with the system-level design.

The contractor shall also define high-level expectations and requirements for integrating models of NextGen concepts of operation in ACES in accordance with NextGen Airspace Project milestones. Requirements shall include specifications of the concept elements to be modeled and their required levels of modeling fidelity.

The contractor will further update any ACES development plan. Accordingly, the contractor shall refine expectations, define detailed requirements, and incorporate current and maturing concepts of operation within ACES as needed to meet project milestones. The requirements shall include specifications of the NextGen concept elements to be modeled and their required levels of modeling fidelity.

7.9 Scenario Development and Analysis (Option Years Only)

NASA intends to generate ACES scenarios to support research in ASDO, Surface, DAC, TFM, and SA. The contractor will support ACES scenario development in such cases, as each area is more clearly defined. The list below shows the current understanding of the scope of this effort. The contractor will develop the necessary scenario data, perform an analysis using ACES, and report on the results. NASA will provide Government Furnished Information (i.e., software and engineering design documents) to guide the contractor's scenario development.

7.9.1 Requirements

7.9.1.1 The contractor shall generate advanced terminal area configurations to adequately represent concepts in ASDO and Surface in conjunction with the existing STLE and TME models.

7.9.1.2 The contractor shall generate scenarios representing NextGen DAC operations.

7.9.1.3 The contractor shall generate scenarios representing NextGen TFM operations.

7.9.1.4 The contractor shall generate scenarios representing NextGen SA operations.

7.9.1.5 The contractor shall analyze the developed scenarios using ACES.

7.9.1.6 The contractor will extract and analyze metrics of the scenarios.

7.10 Models Integration

The contractor will integrate any models developed by or for NASA and its collaborators into ACES. The models include but are not limited to TME, Neighboring Optimal Wind Route, FACET, Airspace and Traffic Operations Simulation (ATOS), CTAS, and those presented in previous sections. NASA will specify the models for integration.

7.10.1 Requirements

The contractor shall provide the following:

7.10.1.1 Integration support and maintenance for the ACES infrastructure and architecture to support performance improvements that makes it easier to incorporate new elements and models into ACES simulations.

7.10.1.2 Integration of new elements and models into ACES.

7.11 Custom Tools and Models Support

The contractor shall integrate any tools (including pre- or post-processing) developed by or for NASA and its collaborators into ACES toolbox. These tools include but are not limited to Automated Terminal Area Node-link Generator (ATANG), Terminal Area and Airport Surface Editor (TAASE), National Airspace System Performance Analysis Capability (NASPAC), Airport and Airspace Simulation Model (SIMMOD), Runway Delay Simulation Model (RDSIM), Airport Delay Simulation Model (ADSIM), Man-machine Integration Design and Analysis System (MIDAS), and SystemwideModeler.

Description: ATANG automatically generates a detailed node-link network of a given airport, capturing the complicated connectivity between taxiways and runways.

ATANG development was initiated to address the increasing demand for detailed terminal area information to be used with various analysis and simulation tools such as ACES, Surface Management System (SMS), and Airspace Traffic Generator (ATG). ATANG is one of the first tools to deliver the automated node-link generation capability, which is applicable to wide range of different airports.

ATANG reads in airport GIS data file, generated from the Safe Flight 21 data, and processes the polygons using series of computational geometry routines to create the node-link model. ATANG provides a GUI to examine the generated node-link graph and outputs to various formats including Google Earth KML for universal viewing.

ATANG successfully processed 14 most complicated US airports among 80 available airports from the Safe Flight 21 data set.

Description: TAASE is a software tool to support the development and maintenance of a standard set of terminal airspace descriptions and airport surface descriptions for use by NextGen Airspace and Airportal Project researchers.

7.12 Final Release Preparation

The contractor shall prepare the final version of ACES to be released to the general airspace analyst community.

Description: This includes formulating a formal system of distribution, bug tracking, and user support, beyond what is supported by NASA.

7.13 Future Implementation Recommendations (CDRL 27, Last Option Year Only)

The contractor shall perform a general “gap analysis” that identifies capabilities that should be added to ACES to improve the ability to model and evaluate future airspace concepts and scenarios.

The contractor shall deliver a report on this analysis according to the schedule specified in the CDRL.

7.14 Contractor Review and Communication

The contractor shall conduct a review with NASA every six months to evaluate the project progress. A written evaluation of performance will be produced at the end of each period. Review criteria includes, but are not limited to, the responsiveness of the contractor to addressing NASA requirements and requests.

In addition, teleconferences and meetings between the contractor and NASA will be conducted as needed.

Appendix A. NASA On-Site Resources

The following is a list of the facilities and types of access that NASA will provide to the contractor.

- ACES Laboratory: The contractor will have access to the ACES Laboratory located at NASA Ames Research Center.
- On-site simulation computers: The contractor will have access to the ACES computer strings to install and test new software releases (after proper NASA training) that conform to the currently established form of ACES releases. The contractor will also have access to the ACES computer strings to conduct research simulations and analyses in support of this SOW topic. However, all installations, simulations, and analyses will be subject to approval by NASA's ACES management team.
- On-site servers: The contractor may have access to on-site, external servers for configuration management applications, as required, to maintain software for ACES development.

NASA will provide the contractor with the following on-site support:

- Place and time of performance: The primary work location is Building 210, NASA Ames Research Center, Moffett Field, CA. Work hours normally range from 0600-1800, Monday through Friday.

- Government-Furnished Equipment: The Government will provide the contractor office space, furniture, and equipment, which will include basic office automation equipment and networking connectivity to perform the tasks associated with this research activity. The performer may bring its own computer equipment to use on-site provided the equipment complies with Government information technology requirements for network access.

- Work space: The Government will provide workspace for the contractor's staff within Government facilities.

- Automation equipment: If requested, the Government will provide a standard personal computer, standard office automation software, and local area network access to perform the requirements of the contract.

- Supplies: The Government will provide expendable supplies, including paper, pencils, folders/binders, paper clips, and cleaning materials.

- Printing and reproduction: The Government will provide the performer with copier and printer capabilities for limited quantity letter and/or legal-size documents within the performer's workspace.

- Telephones: The Government will provide access to local and long distance telephones.

- Conference rooms: The Government will provide access to conference rooms when available as needed for teleconferences, classes, committee sessions, and working groups. The Government will also grant permission to use teleconferencing equipment, overhead projectors, VCRs, dry erasure boards, video projection units, and other equipment as needed provided the performer does not remove the equipment from the site.

Appendix B. ACRONYMS

AAC	Advanced Airspace Concept
AAR	Airport Acceptance Rate
ACES	Airspace Concepts Evaluation System
ADSIM	Airport Delay Simulation Model
AFRL	Air Force Research Laboratory
AOC	Airline Operations Center
AP	Airportal
ARTCC	Air Route Traffic Control Center
AS	Airspace
ASDO	Airspace Super Density Operations
ATANG	Automated Terminal Area Node-link Generator
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATG	Airspace Traffic Generator
ATM	Air Traffic Management
ATOS	Airspace and Traffic Operations Simulation
BADA	Base of Aircraft Data
CARP	Constrained Airspace Reroute Planner
CD&R	Conflict Detection & Resolution
CDRL	Contract Data Requirements List
CMMI-SE/SW	Capability Maturity Model Integration – Systems Engineering/Software Engineering
CNS	Communication, Navigation, and Surveillance
CVS	Concurrent Versions System
CWAM	Convective Weather Avoidance Model
DAC	Dynamic Airspace Configuration
EDD	Engineering Design Document
FAA	Federal Aviation Administration
FACET	Future ATM Concepts Evaluation Tool
GA	General Aviation
GIS	Geographic Information System
GUI	Graphical User Interface
HLA	High Level Architecture
IDE	Integrated Development Environment
JPDO	Joint Planning and Development Office
MAP	Monitor Alert Parameter
McTMA	Multi-center Traffic Management Advisor
MIDAS	Man-machine Integration Design and Analysis System

NAS	National Air Space
NASA	National Aeronautics and Space Administration
NASPAC	National Airspace System Performance Analysis Capability
NextGen	Next Generation
NFS	Network File System
NGATS	Next Generation Air Transportation System
NPR	NASA Procedural Requirements
NRA	NASA Research Announcements
RCP	Required Communication Performance
RDSIM	Runway Delay Simulation Model
RNP	Required Navigation Performance
RSP	Required Surveillance Performance
RTSP	Required Total System Performance
RNAV	Area Navigation
RUC	Rapid Update Cycle
RVR	Runway Visual Range
RVSM	Reduced Vertical Separation Minimum
SA	Separation Assurance
SDD	Software Design Document
SDP	Software Development Plan
SESO	Safe and Efficient Surface Operations
SIMMOD	Airport and Airspace Simulation Model
SLDAST	System-Level Design, Analysis, and Simulation Tools
SMS	Surface Management System
STLE	Surface Traffic Limitations Enhancements
TAASE	Terminal Area and Airport Surface Editor
TAP	Terminal Area Plant
TCP/IP	Transmission Control Protocol/Internet Protocol
TFM	Traffic Flow Management
TIP	Task Implementation Plan
TMA	Traffic Management Advisor
TME	Terminal Model Enhancement
TPSU	Trajectory Prediction, Synthesis, and Uncertainty
TRACON	Terminal Radar Approach Control
VFR	Visual Flight Rule
XML	Extensible Markup Language

Appendix C. Example of an Engineering Design Document

SEE SECTION J.1(a)2

Appendix D. References

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Number	Title	Description	Year	Metrics
AS.1.7.03	Develop individual agent-based models of NGATS technologies		FY08	These models shall include at least ASDO, TFM, SA, and DAC
AS.1.7.04	Develop interim system-level concept of operations to accommodate 3x demand based on results of studies and identified gaps.	The interim concept of operations will document any modifications to the initial concept of operations based on results of analysis, prototypes, and simulations. It will also identify the changes and their rationale from the initial version. The concept of operations will also identify the gaps to achieving the NGATS vision.	FY09	Less than 50% change from initial version and stakeholder vetted.
AS.2.7.01	Develop method for modeling human workload in fast-time simulations, validate models against workload measurements.	Human workload is a critical limitation on current NAS operations. Under NGATS, automation will play a greater role, but humans will still play important roles in NAS operations. To effectively study the benefits/limitations of new NGATS concepts, human workload needs to be represented in the fast-time simulations that are used to model the NAS. Initially, workload for humans in current day operations must be modeled and those models validated against available real world data. This provides baseline workload models for comparison with models representing future transitional states as the	FY10	Method reduces the uncertainty bounds by 50% for typical Air Midas analyses.

		NAS migrates toward the NGATS concept of operations. As the role of humans in NGATS concepts becomes better defined, workload models for those roles will be updated.		
AS.3.7.01	Conduct objective analysis of service provider and aircraft operator separation assurance methods.	Analyze central service provider- and aircraft operator-based separation assurance methods based on factors such as scalability, trajectory modeling requirements, surveillance performance, trajectory coordination, traffic density, traffic conditions (nominal, metering, severe weather, terminal), analytic or rule-based algorithms, error conditions, system architecture, failure modes, human cognition and workload, cost to equip, and safety. The analysis will consider en route and Super-Density operations in the presence of hazardous weather and under time-based metering conditions.	FY10	Stakeholder vetting and peer review
AS.3.7.02	Develop fast-time system-level simulation of NGATS technologies.	The fast-time system-level simulation of NGATS technologies will include the Agent-based models of ASDO, SA, TFM, and DAC technologies from AS.1.7.03. These models will be integrated together using the con-ops developed in AS.1.7.04 as a guide.	FY10	The system-level simulation includes models of ASDO, SA, TFM, and DAC technologies.
AS.3.7.03	Develop tools for generating future demand scenarios and analyzing NGATS data.	Future demand scenarios will be required for driving system-level analyses of NGATS technologies. Similarly tools will be needed to analyze NGATS data. NGATS data will be data outputs from system-level simulations and data collected from the NAS.	FY10	1x, 2x, and 3x demand scenarios can be generated. NGATS data analyses will generate metrics that answer critical NGATS questions.
AS.4.7.01	Develop refined sys-tem-level concept of operations based on results of modeling, safety, cost-benefits, and human-in-the-loop simulations	The concept of operations will include both nominal and off-nominal conditions. The document will de-scribe concepts, technologies, information needs, functions, and roles and responsibilities. The concept of operations will also identify the rational for changes from the initial version and completeness and gaps in meeting the NGATS vision. Analyses performed using the NGATS system-level simulation from AS.3.7.02 will also guide development of the con-ops.	FY11	A refined concept of operations will be de-livered.
AP.2.S.03	Develop algorithms to generate robust optimized solutions for surface traffic planning and control	The research focus is to develop system architecture and algorithms to generate optimized solution(s) for surface traffic planning and control including taxi routes and runway schedule, to allow surface throughput gains with little or no increase in delays. The solution will cover the entire domain of surface operations including ramps, taxiways, and runways. The objective is to increase runway throughput and taxi efficiency while satisfying system constraints. The algorithms must be robust so that they will work efficiently in the presence of various uncertainties. Both deterministic and stochastic optimization approaches will be explored. Computational performance requirements for real-time applications will be investigated.	FY09	For each optimization solution method developed, solve for surface traffic planning problems for at least two major airports for both current-day traffic demand and future demands (e.g., 2x). Compare efficiency metrics (e.g., taxi delays, runway queue lengths) and runway throughput for each solution method. Compare robustness of the solutions against uncertainties. Goal is to demonstrate increased runway throughput and improved surface movement efficiency while satisfying identified system constraints.
AP.3.S.02	Integrate and evaluate surface traffic planning algorithms/tools in fast-time simulation environment	Integration of taxi route planning, runway schedule, environmental model, and surface operations data analysis into a fast-time simulation environment. Test optimized taxi routes meeting departure schedule constraints. The departure scheduler provides optimal schedule as input to taxi route solution. Taxi optimization solution generates time-based taxi routes that minimize overall taxi delays and maximize runway throughputs. Conduct fast-time simulations to evaluate the benefits in both normal and off-normal conditions.	FY11	Via fast time simulation to show the ability to manage 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 is based on comparison to taxi routes

				developed by subject matter experts presented with the same 1X and 2X traffic-demand scenarios. Results are used to feed benefits analysis and trade studies to assess potential utility of taxi route optimization.
AP.4.S.01	Initial validation of four-dimensional (4D) trajectory-based safe and efficient surface operation functions and procedures	Perform validation of automated, safe, and efficient surface operations for normal and off-normal conditions through fast- and real-time simulations. Fast-time simulations are used to evaluate performance of integrated functions. Real-time simulations with human-in-the-loop (flight deck and service providers) will be used for assessing effectiveness of computer generated clearances and advisories.	FY11	Metrics include runway throughput, average taxi delays at 2x and 3x operations, exceedance of environmental constraints at 2x and 3x, maximum throughput available within environmental constraints, fuel savings, runway crossing time compliance, efficacy of runway incursion techniques, and system operator acceptance/ compliance of taxi clearances. Metrics compare simulation findings with 2005 published operational performance at 3 major airports. Metric targets to be established by ATIM system analysis studies.

AS: Airspace
AP: Airportal