

NASA System-Level Design, Analysis and Simulation Tools Research on NextGen

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ABSTRACT

A review of the research accomplished in 2009 in the System-Level Design, Analysis and Simulation Tools (SLDAST) of the NASA's Airspace Systems Program is presented. This research thrust focuses on the integrated system-level assessment of component level innovations, concepts and technologies of the Next Generation Air Traffic System (NextGen) under research in the ASP program to enable the development of revolutionary improvements and modernization of the National Airspace System. The review includes the accomplishments on baseline research and the advancements on design studies and system-level assessment, including the cluster analysis as an annualization standard of the air traffic in the U.S. National Airspace, and the ACES-Air MIDAS integration for human-in-the-loop analyzes within the NAS air traffic simulation.

INTRODUCTION

As the air traffic demand increases to levels that are not sustainable by the air traffic management system, NASA has been mandated by Congress to support the development and implementation of the Next Generation Air Transportation System (NextGen) of the U.S.A. National Air Space (NAS). This national effort is led by the Joint Planning and Development Office (JPDO) "to retain U.S. leadership in global aviation, expand capacity, ensure safety, protect the environment, ensure our national defense, and secure the nations" [1].

Although the estimated air traffic demand is subject to forecasts under present economic uncertainties, the benefits of NextGen are important as the latest 2011 report of the Federal Aviation Administration entitled "FAA's NextGen Implementation Plan" [2] states:

"NextGen is a comprehensive overhaul of our National Airspace System to make air travel more convenient and dependable, while ensuring your flight is as safe, secure and hassle free as possible. ... Our latest estimates, which are sensitive to traffic and fuel price forecasts, indicate that by 2018, NextGen will reduce total delays (in flight and on the ground) by about 35 percent compared with what would happen if we did nothing. That delay reduction will provide, through 2018, \$23 billion in cumulative benefits to aircraft operators, the traveling public and the FAA. In the process, we will save about 1.4 billion gallons of aviation fuel during this period, reducing carbon dioxide emissions by 14 million tons."

NASA as a partner agency has established the Airspace Systems Program (ASP) to lead the foundational research to enable the development of revolutionary improvements in support of NextGen. This research is mainly conducted at Ames Research Center and Langley Research Center in collaboration with industry research contracts, academia research agreements, and other federal agency cooperative agreements.

AIRSPACE SYSTEMS PROGRAM

The Airspace Systems Program (ASP) focuses on new concepts, capabilities, and technologies in fundamental air traffic management research to enable significant increases in capacity, efficiency, and flexibility on the National Airspace System (NAS). ASP has recently been re-organized into two projects: Concepts and Technology Development (CTD), formerly NextGen-Airspace, and Systems Analysis, Integration & Evaluation (SAIE), formerly NextGen-Airportal [3, 4].

The NextGen CTD Project focuses on developing capabilities to significantly increase air space and surface terminal capacity, efficiency and safety. New fundamental concepts

and technologies are being developed at the component level in the following areas of research focus: Traffic Flow Management (TFM) to maximize national-airspace throughput with new processes to address the demand and capacity imbalances from weather effects and system wide uncertainties; Dynamic Airspace Configuration (DAC) to increasing system capacity by bringing to bear available airspace and controller resources and capacity to changes in traffic demand; Separation Assurance (SA) to increase capacity through higher levels of automation, scheduling sequencing, merging, and spacing, and ensure safe, on-time, fuel-efficient, en-route flight while allowing for reduced distance between aircraft, under increased air-traffic volumes and varying weather conditions; Super Density Operations (SDO) to optimize timely arrivals, departures and surface operations through fuel-saving “continuous descents,” arrival/departure-time management, route modification and adaptive speed control; and Safe and Efficient Surface Operations (SESO) to achieve the most effective pace for such surface operations as taxiing, departures, landings and gate arrivals.

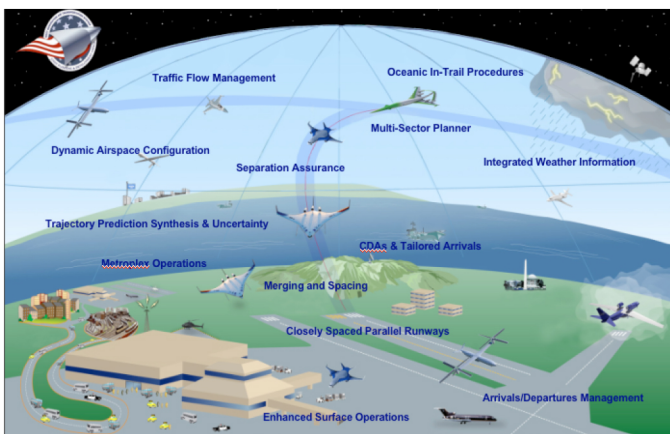


Figure 1. Areas of Research Focus of the Airspace Systems Program.

The NextGen SAIE Project focuses on the integrated systems analysis of the fundamental concepts, technologies and procedures to determine their NextGen viability “*through evaluation in relevant environments, providing integrated solutions, characterizing airspace system problem spaces, defining innovative approaches, and assessing the potential system impacts and design ramifications of the Program's portfolio.*” This project has three areas of research focus: Integration, Evaluation and Transition (IET) to evaluate concepts & technologies of the program in relevant environments; Interoperability Research (IR) to research the integration and the interaction of multiple fundamental concepts and technologies within the research portfolio across the research focus areas of the program; and System and Portfolio Analysis (SPA) to perform systems studies to identify the system benefits or impacts of the program's

concepts and technologies to the program and to researchers and developers.

SYSTEM-LEVEL DESIGN, ANALYSIS AND SIMULATION TOOLS

System-Level Design, Analysis and Simulation Tools (SLDAST), formerly a research focus area of the NextGen-Airspace Project, is currently a major component of the SAIE Project. This paper presents a comprehensive view of the 2008 SLDAST milestones and accomplishments.

In 2009, SLDAST addressed the system-level design, analysis and simulation requirements of the ASP Program. Research focused on the development of simulations and requirements needed to achieve a comprehensive understanding of the benefits and the integrated benefits of the future NextGen technologies and concepts developed in the program. The challenges of the research is increased by the programmatic need of early-on assessments of selected future technologies and concepts under study in the different research focus areas of the program, their integration on the National Airspace System (NAS) that has naturally evolved through the years into a very complex system with multiple stakeholders sustaining diverse and conflicting objectives, and the need to reach an understanding of the complex interactions in the system with different traffic demands and capacity levels. The technological advances will undoubtedly change the NAS, implying that the changes in NextGen behavior have to be determined and assessed.

Presently the insertion of new technology and procedures into the NAS is normally conducted at the component level using prototyping and iterative human-in-the-loop simulation with limited or no system-level design constraints that effect the design or even provide feedback to the design of a new fundamental concept or technology. SLDAST has been conceived to provide a common foundation to the program and early information on NextGen concepts and technologies. To address the complexity of the system, SLDAST has defined a set of different levels of research focus, a baseline research on common definitions, scenarios, metrics and assumptions including; a set of design studies across different research focus areas of the program; and a set of system-level assessments of multiple NextGen fundamental concepts and technologies. The following [Fig. 2](#) shows the SLDAST program milestones with the baseline research on top, the system-level assessments in the middle, and the design studies at the bottom.

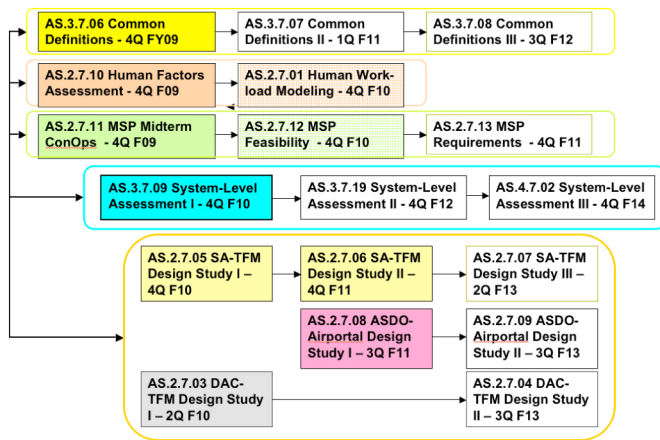


Figure 2. SLDAST Milestones.

A common programmatic environment in the simulation of the design studies and the system-level assessments is the Airspace Concept Evaluation System (ACES) [5] being developed at Ames Research Center and funded by SLDAST to enable the evaluation of the system-wide effects of the NAS and the proposed NextGen concepts and technologies to increase capacity, reduce delays, and accommodate the forecast growth in air traffic. It will also incorporate a large set of improvements on surface and air capacity envisioned within NextGen technologies, as it is described in the JPDO's NextGen Implementation Plan and the NextGen concepts and technologies [6,7,8].

A brief description of the SLDAST areas of research focus is included below,

- **Baseline Research:** to assess the benefits of NextGen concepts and technologies is necessary to define and develop the supporting common scenarios and simulation models based on the NextGen concepts and technologies and the NextGen Implementation Plan developed by JPDO, including their expected traffic demand levels and their different weather conditions; to define the common assumptions of the studies on time frames, avionics, aircrafts, demand growth, separation assurance, weather, network enablers, and all changes due to the NextGen technologies; and to define the common metrics on capacity, throughput, efficiency, predictability, risk, reliability, safety, system-wide interoperability, and environmental requirements; to define the human factors each study will require to support the design studies and the system-level performance assessments. The baseline studies also include the continued development of the ACES simulation tool of NAS, and the different modifications needed to represent NextGen concepts and technologies, including human in-the-loop factors.

Common Scenario Generation

- **Current Day (2006)**
 - Cluster Analysis
 - NAS Data Gathering
 - Database Generation
 - NAS state data
 - NAS weather data
 - NAS wind data
- **Terminal Area Transit Times**
 - Data Gathering
 - Updated ACES transit times
- **Sector Enhancements for use with ACES**
 - 2006 Sector model
 - Correction of "Gaps and Overlaps" laterally and vertically
 - Alignment of sector boundaries
 - Oceanic coverage
- **Airport Capacity and State**
 - CD-PSCA
 - ASPM
 - JPDO-SMAD + ASPM + CD-PSCA
- **Airport Taxi Times**
 - CD-PSCA
 - ASPM
 - JPDO-SMAD + ASPM + CD-PSCA
- **Demand Generation (TAF 2008)**
 - 1.0x, 1.3x (NGIP (2018)), 1.5x, 1.7x (NextGen (2025)), 2.0x, 2.5x, and 3.0x.
 - Unconstrained version of demand
 - Constrained (time shifted) version of demand
- **Expanded ACES Airport database**
 - Most frequently used terminal area configurations
 - Runway modeled airports (FAA Metro 7 airports)
 - Added aircraft types
- **NGIP (2018) configuration**
- **NextGen (2025) configuration**

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Figure 3. High-level Common Scenario Generation

This research includes a large set of common scenarios (a general description is shown below in Fig. 3), common metrics, and assumptions used across different research focus areas.

A study on metrics was conducted under the Common Definitions milestone. This research defined a common set of metrics for measuring NAS and NextGen performance, and "the metrics are directly traceable to JPDO NextGen goals and objectives and will be useful for measuring the progress of ASP research in enabling NextGen" [9].

The SLDAST research also includes an emphasis on human factors. Specific Human Factors Assessment milestones were established to develop the technology needed to include them into the NAS analysis. The main technical objective was the identification and prioritization of the NextGen Human Factors issues vetted by the relevant human performance research community. The principal technical challenges on this research were the inherent complexity of the NextGen operations, the requirement of comprehensive definitions of the NextGen concepts, including a clear specification of the concept implementations and functions, the context definition of the operational concepts, and the generalization to a system-level complex environment; and most importantly the development of methodologies and specific tools to enable the integration of human factors considerations in-the-loop of the NAS within a NextGen context [10,11,12].

Another significant research on human factors was the development of human workload models suitable for use in fast-time simulations and their integration into the ACES fast-time NAS simulation. This capability supports the NAS evaluations including the concepts on the human operators who are charged with the responsibility of executing and