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Case # 10-2003

MITRE Innovation Program

Research Challenge:

The Next Generation Air Transportation System (NextGen)

MITRE

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Research Challenge:

Next Generation Air Transportation System (NextGen)

Introduction

The Center for Advanced Aviation System Development (CAASD), operated by The MITRE Corporation, is the Federal Aviation Administration's (FAA's) Federally Funded Research and Development Center (FFRDC). CAASD's mission is to advance the safety, security, effectiveness, and efficiency of aviation in the United States and around the world. The center has over 50 years of experience in Air Traffic Management (ATM) modernization and focuses on anticipating the FAA's needs and developing timely solutions that guide transformation to the future global aviation enterprise.

In support of its FFRDC missions, MITRE operates an independent research and development program known as the MITRE Innovation Program (MIP). This program funds research to explore new technologies and concepts to solve our sponsors' problems both in the near-term and in the future. The MIP is organized around a set of investment areas, each targeting an area of critical sponsor need. The goal of one of these investment areas is to accelerate the FAA's Next Generation Air Transportation System (NextGen).

This brochure describes MITRE's NextGen research strategy, our targeted research outcomes, and the NextGen research portfolio of investments.

Expediting the Next Generation Air Transportation System

NextGen is not a single system or program but rather a congressionally mandated initiative to modernize the U.S. air transportation system. NextGen's goals include increasing the capacity and reliability of the system, improving safety and security, and minimizing aviation's environmental impact. The plans for NextGen were developed through an inter-agency Joint Planning and Development Office (JPDO) whose members include the FAA, the National Aeronautics and Space Administration (NASA), the Departments of Transportation, Homeland Security, Defense, and Commerce, as well as the White House Office of Science and Technology Policy.

The conduct of NextGen research is an important element of MITRE's strategy to accelerate NextGen. In assembling a NextGen portfolio we wanted to focus our research on a small set of critical problems where MITRE can have particular value and impact. We focused the portfolio on three research challenges:

- "Weatherproofing" the National Airspace System (NAS)
- Enabling regular operations of Unmanned Aircraft Systems (UAS) in civil airspace
- Building stakeholder consensus around NextGen concepts, policies, and procedures.

These areas were chosen because they leverage our strengths in tools and technical expertise and corporate knowledge, are well aligned with our FFRDC mission, and leverage a broad set of innovative, forward-looking ideas being brought forward by MITRE technical staff.

“Weatherproofing” the NAS

It is estimated that weather accounts for approximately 70 percent of all delays in today’s NAS. The JPDO asserts that two-thirds of these delays are avoidable. This represents a savings potential of $19 billion or more a year.

Today’s system operates best under visual flight conditions. Capacity is degraded under poor visibility conditions because pilots and controllers, due in part to a lack of sensors and decision support tools, must increase aircraft separation in order to ensure safe operations. When pilots lack positive visual contact with other aircraft, obstacles, or the airport surface, or when controllers cannot provide visual separation between aircraft, extra operational safety margins must be built in, decreasing system capacity.

This represents an opportunity: What if we could provide pilots and controllers situational awareness equivalent to what they have under visual conditions?

RESEARCH OUTCOME 1a: Develop, prototype and demonstrate new tools, technologies, and procedures to enable visual-like operations even under Instrument Meteorological Conditions (IMC) (or other poor weather). Quantify the effectiveness from both a safety and capacity perspective of these solutions, and assess conditions and locations under which they are applicable.

Another critical weather problem in U.S. airspace arises from severe weather activity. Severe weather such as lines of summer thunderstorms can significantly disrupt the flow of aircraft. Current safety norms do not permit flying commercial aircraft through thunderstorms; frequently these storms extend high into the atmosphere and flying over them is precluded. Traffic patterns around the weather become complex and difficult for air traffic controllers to handle, further decreasing throughput. Traffic flow managers need better tools to forecast and track these events and to re-plan traffic in and around them in a safe and effective manner.

RESEARCH OUTCOME 1b: Develop, prototype and demonstrate new tools, technologies, and procedures to manage the safe and efficient flow of aircraft in the presence of severe weather activity. Quantify the effectiveness (from both a safety and capacity perspective) of these solutions, and assess conditions and locations under which they are applicable.

Regular Operations of UAS in Civil Airspace

In recent years UAS have become a critical component of our nation’s defense strategy. UAS demand in the Department of Defense has grown exponentially, and we are beginning to see major shifts in the acquisition strategies of the various branches of the military toward the use of unmanned aircraft for reconnaissance and other missions that are “dull, dirty, or dangerous.”

Industry experts see this military trend as presaging an even larger trend toward applying UAS in civilian applications. Law enforcement, traffic monitoring, real estate sales, and crop dusting are but a few of the many civilian uses of unmanned aircraft now being discussed. Between these emerging civilian applications and the needs of the military there is now a groundswell of interest in being able to fly UAS intermingled with manned aircraft in the NAS.

One major area of concern, however, is that all of the systems, rules, regulations, standards, concepts, tools, technologies, and procedures underpinning today's ATM systems were developed under the assumption of manned cockpit operations. In fact, the fundamental concept of see-and-avoid—that the pilot is ultimately responsible for situational awareness and avoiding of surrounding aircraft—assumes there is a pilot in the cockpit.

Nearly all of today's UAS operations consist of remotely piloted aircraft. A pilot, sitting at a ground-based control station, flies the aircraft by remote control with a Command and Control (C2) communications link relaying real-time flight instructions. In general, these remote pilots rely 100 percent on instrumentation for flying the aircraft—they do not have a visual out the window situational awareness. A major research question, therefore, is how to replace the traditional see-and-avoid function with an equivalently safe and effective sense-and-avoid function for UAS.

RESEARCH OUTCOME 2a: Develop and mature alternative UAS sense-and-avoid solutions, evaluate and demonstrate their effectiveness, and assess their economic viability to inform policy decisions.

Since nearly all UAS are remotely operated, they are highly dependent on a reliable air-ground C2 link. Any meaningful safety analysis, however, must take into account the possibility of a loss of this communications link. UAS need to be able to safely perform at some level of autonomous operation and the ATM decision support systems, pilots, controllers, and procedures of the NAS need to be able to safely accommodate these failures as well. The question is how can UAS and the staff and automated systems of the NAS respond in a safe and resilient manner to the loss of the air-ground command link?

RESEARCH OUTCOME 2b: Identify specific operational challenges surrounding UAS C2 failure, propose alternative solutions, and demonstrate their technical feasibility and operational effectiveness.

Building Stakeholder Consensus

For NextGen to become a reality there must be alignment of thinking and action across a very diverse set of decision makers and stakeholders. Government agencies need to deploy new systems and concepts, airlines need to purchase appropriate equipment and train staff, pilots and controllers need to agree on new procedures, airport authorities need to make changes to operations, manufacturers need to agree on standards and ramp up production, etc.

They say "seeing is believing"—MITRE is bringing the pieces of NextGen alive in our laboratories and bringing the key stakeholders into the process so they can see it, understand it, and work with us to refine the pieces.

RESEARCH OUTCOME 3a: Build Human-In-The-Loop simulations and analytical models to "bring NextGen alive" in a realistic simulation environment. Expand the range of stakeholders whose concerns are quantitatively addressed.

Just building laboratory simulations is not enough. We need to reach out and connect the diverse stakeholder communities. A key element of our strategy is to link the simulation communities but there is also a cultural divide that we must span. The progression to NextGen involves seven government agencies plus coordination with other global air traffic modernization efforts. Each agency's culture has its own needs, priorities and issues. We need to research ways to effectively bridge these diverse cultures.

RESEARCH OUTCOME 3b: Connect stakeholder communities through integrated modeling and simulation environments. Improve mutual comprehension.

Enabling Research

In addition to these outcome-focused research investments, we realize that there are key enabling research efforts which we need to invest in from time to time. These are cross-functional research topics that have broad applicability to the success of NextGen and of the range of research initiatives we are undertaking.

The FY2010 NextGen MIP Research Portfolio

The following are descriptions of the 25 research efforts currently funded under MITRE's NextGen investment area. They are organized around the three broad research challenge areas and the supporting research outcomes.

“Weatherproofing” the NAS

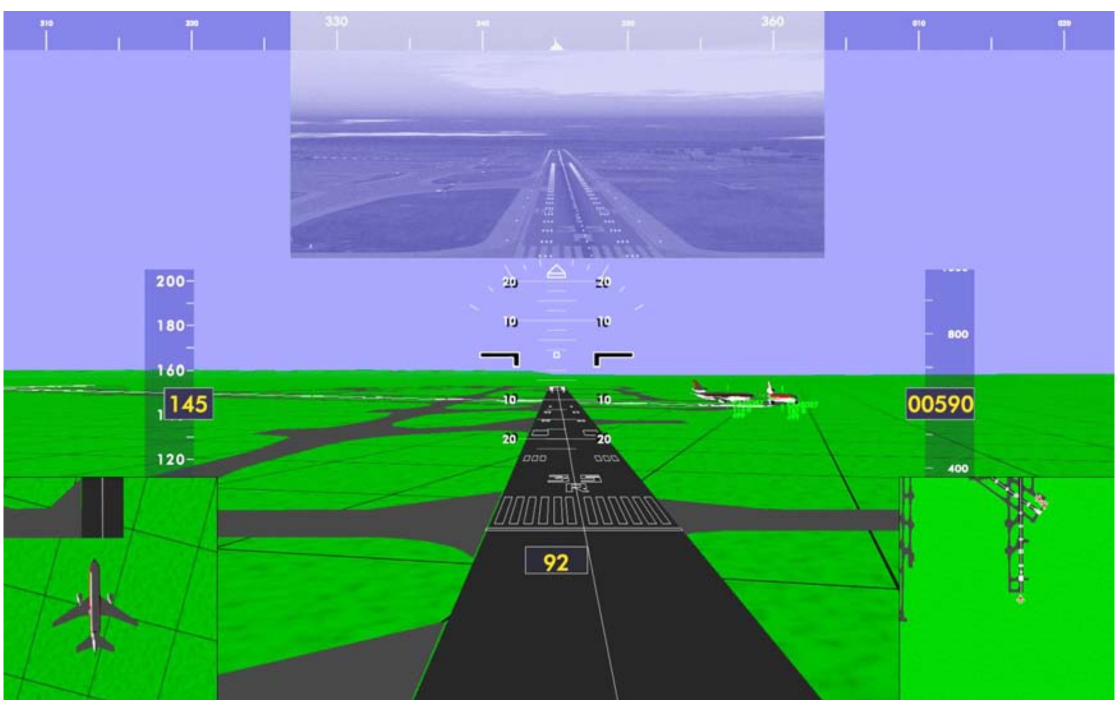
Outcome 1a: Visual-Like Operations Under IMC

These research activities are aimed at achieving the research outcome of developing, prototyping and demonstrating new tools, technologies, and procedures to enable visual-like operations even under IMC, quantifying the effectiveness of these solutions, and assessing conditions and locations under which they are applicable.

Integrated Equivalent Visual Operations

The safe and efficient flow of traffic at U.S. airports is heavily dependent on visual operations. When pilots or controllers acquire traffic visually and provide visual separation for the operations, the throughput of the airport is high. Conversely, when visual operations cannot be supported, the operations in the NAS degrade enormously, resulting in significant delays throughout the system. For example, separations over a single runway threshold can be nearly a mile shorter during visual operations than under radar-based separation. Departures are also more efficient during visual conditions than they are under instrument conditions.

In the Integrated Equivalent Visual Operations project, we are developing concepts that rely on the integration of several emerging technologies to achieve the equivalent of visual operations during bad weather. These technologies include Automatic Dependent Surveillance–Broadcast (ADS-B), Cockpit Display of Traffic Information (CDTI), Area Navigation (RNAV), Required Navigation Performance (RNP), wake vortex transport prognosis, Enhanced Vision Systems (EVS) and Synthetic Vision Systems (SVS).



Enhanced Vision System Conceptual Prototype

Work to date has identified a number of promising operations that depend on combinations of these technologies. These operations include single and parallel arrival and departure operations into and out of airports, as well as more efficient airspace operations through such capabilities as closer spaced parallel routes and cockpit-based separations for transitions into and out of en route airspace. These procedures are being tested for pilot and controller acceptance initially in MITRE's laboratories. Field trials are planned for future work.

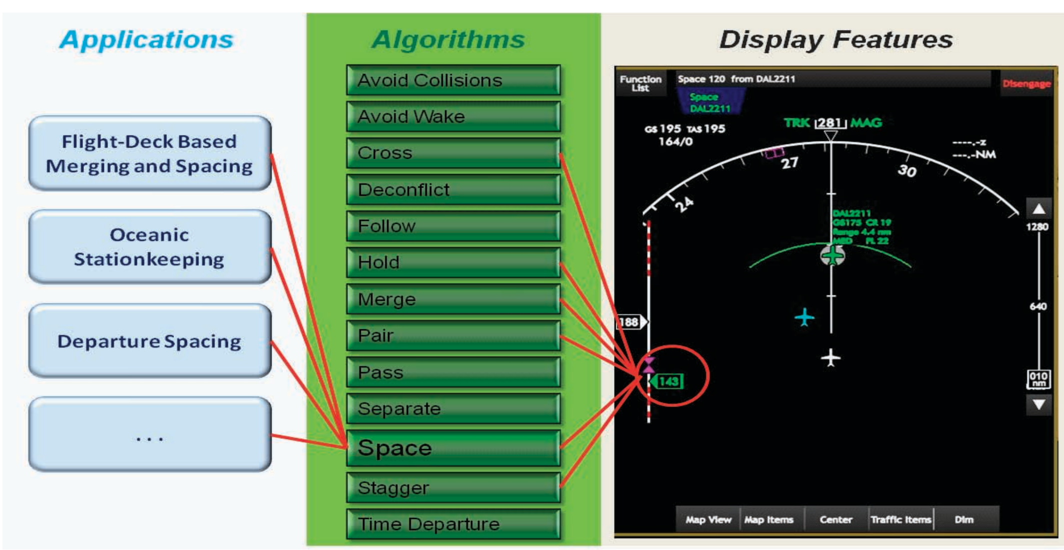
Multi-Purpose Cockpit Display of Traffic Information

NextGen will use CDTI, ADS-B, and other new technologies and procedures to enable a new role for the cockpit; however, to take advantage of these advances, aircraft must first be appropriately equipped. For some users the value proposition of this investment is currently unclear.

The objective of this research is to demonstrate a CDTI that can support a large set of ADS-B applications across a range of flight and ground operations. To accomplish this, the project is creating a suitable CDTI specification, and developing and demonstrating a simulation prototype that represents the envisioned capabilities.

Based on a review of proposed ADS-B/CDTI applications, we identified the algorithmic and user interface requirements of a flexible, multi-purpose CDTI. We designed and prototyped the capability in MITRE's ATM laboratory and demonstrated its value using a range of applications. An initial experimental evaluation has yielded insight into potential design improvements, which are being incorporated and will be evaluated in a second experiment. In addition, the design is being reassessed to ensure that it remains consistent with changes in the aviation industry's ADS-B applications development efforts.

This project is intended to demonstrate the feasibility of a flexible, multi-purpose CDTI technology. Our aim is to attract the attention of stakeholder groups on the technological need and opportunities and help users to better understand the CDTI value proposition.



Multi-purpose CDTI Components

Enabling NextGen Operational Improvements with Wake Turbulence Avoidance Automation

Aircraft naturally generate air turbulence patterns known as wakes, which can be hazardous to trailing aircraft, particularly for operations on airport approach and departure where aircraft are often closely spaced. As NextGen concepts move toward increasing en route and terminal throughput, wake turbulence separation may become a limiting factor in the pursuit of capacity improvements. Better knowledge of the probable location of wakes (for air traffic controllers as well as pilots) could help provide safe separation from wake turbulence while avoiding unnecessary restrictions to operations.

The objective of this research is to determine what increased information can realistically be provided to pilots and controllers to enable reduced aircraft separations without generating an increase in wake encounter events.

Using available data on temperature profile, eddy dissipation rate, and wind fields, current algorithms can reliably estimate wake characteristics. These algorithms will be used to drive display prototypes of wake information on air traffic control workstations and pilot CDTIs. Evaluations will be conducted in MITRE's ATM laboratory to identify the best method for conveying this important wake data to controllers and pilots.

“Weatherproofing” the NAS
Outcome 1b: Managing Flow for Severe Weather

These research activities are aimed at achieving the research outcome of developing, prototyping and demonstrating new tools, technologies, and procedures to manage the safe and efficient flow of aircraft in the presence of severe weather activity, quantifying the effectiveness of these solutions, and assessing conditions and locations under which they are applicable.

Reinventing High Density Area Departure/Arrival Management

The National Airspace System is a complex dynamic system that can exhibit unpredictable behavior during disruptive events such as severe weather. In order to enable safe and efficient flow of aircraft in NextGen, it is critical to ensure stable operations in the presence of disruptive weather events. Arrivals and departures in high density terminal areas are particularly sensitive to such disruptions. A contributing factor to this instability is the fact that the point of action (the airport tower) is far removed from the point of traffic flow decision making (the Air Route Traffic Control Center, [ARTCC]). We are developing a capability to address this problem.

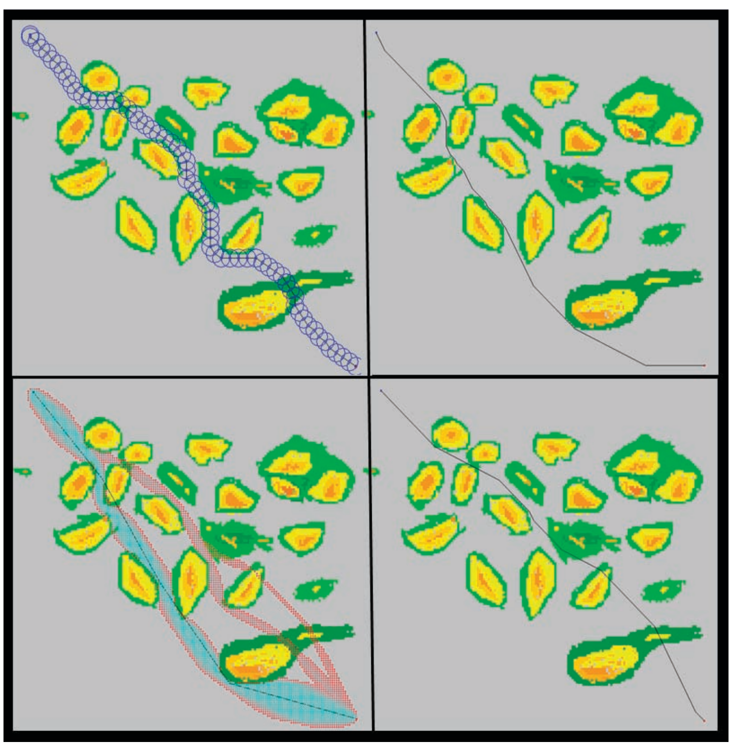
In our concept, instead of the ARTCC’s Traffic Management Coordinator (TMC) making the decisions on mitigating actions (traffic management initiatives, miles-in-trail restrictions, reroutes, etc.), the TMC would adjust the available capacity over each departure fix and departure route for each time period based on predicted traffic and weather information. Automation would translate this into required “wheels off” times for departing aircraft. The TMC in the tower would work together with the airline operation centers to accurately assign “push back” times to individual aircraft. This method would work cooperatively with the collaborative departure queue management concept the FAA is pursuing for mid-term NextGen.

A series of experiments in MITRE’s ATM laboratory are being prepared to analyze the feasibility and benefit of the proposed concept. The roles and responsibilities of the traffic managers in each facility of the proposed concept will be simulated and compared with today’s operation. These experiments will explore the functions/capabilities and the level of automation needed to support the proposed concept.

Trajectory-Based Operations in Severe Weather

When operating in the vicinity of severe weather, aircrafts' intent information is limited in the 0-20 minute tactical en route timeframe. Weather avoidance is negotiated between the pilot and controller verbally, and weather avoidance clearances are usually issued as open-clearance vectors or occasionally altitude changes. The vectors are often at the pilot's discretion and the point at which the pilot will return to the original route is sometimes unknown by the air traffic controller. This leads to uncertainty and difficulty in maintaining intent for Trajectory Based Operations (TBO). In TBO, the automation expects a closed clearance for the purposes of problem detection and resolution. Without a closed clearance, weather problems in this timeframe must be handled more tactically, relying on procedures similar to those used today.

Previously, MITRE evaluated the use of the National Convective Weather Forecast, the Corridor Integrated Weather System and the Weather Avoidance Field for en route weather detection and resolution. In addition, we conducted research into search methods for creating resolutions to deterministic weather problems. Current research includes an assessment of graph/routing algorithms to solve en route tactical weather problems utilizing probabilistic weather products. Included in this assessment will be several different approaches including graph-based algorithms such as Dijkstra and A*, and less conventional approaches such as potential fields. Deterministic weather products are defined as being in only one of two possible states: weather that can be flown through, and weather that must be avoided. Probabilistic weather products are defined as having various degrees of probability of occurrence or that the area will be avoided.



Comparative Weather Avoidance Algorithms

CAASD's en route research prototype, Java En route Development Initiative (JEDI), in conjunction with rapid prototyping techniques, will be leveraged in this research. Utilizing current functional performance methods, analysis will be performed to determine the most appropriate algorithm based on factors such as path cost, successful resolutions, and computation time. CAASD in-house operational experts will be used to determine operational acceptability of the resolutions.

This research proposes more accurate and stable trajectories for problem prediction, resolution, and metering functions, leading to improved ability to maintain TBO in tactical en route operations in the vicinity of severe weather.

NextGen Air Traffic Control (ATC) Display

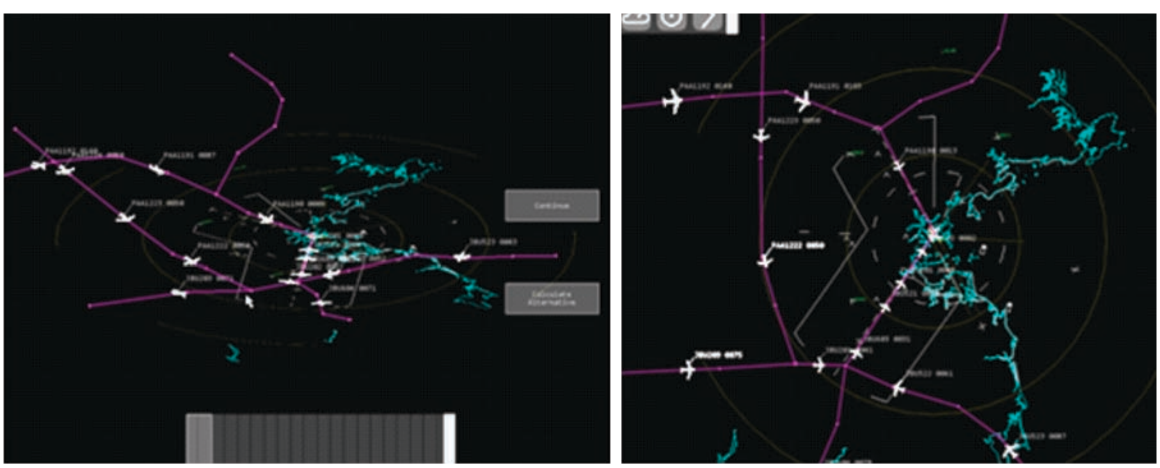
NextGen is expected to incorporate new tools and capabilities, such as RNAV, data communication, ADS-B, and automated decision-making tools. These new capabilities are expected to significantly change the nature of the air traffic controller's task toward a more supervisory one. Automation will identify problems and generate solutions, and one of the controller's tasks will be to monitor, evaluate, and modify those solutions. The aim of this research is to look at the implications of this change in the controller's task for ATC display functionality. We intend to develop an ATC display prototype that facilitates an efficient and intuitive interaction between the controller and the automation in the NextGen timeframe.

We began by developing a model that outlines the interaction between the controller and the automation. The model includes roles and responsibilities of each agent, as well as the exchange of information between the two. Based on the controller-automation interaction model, we adopted the following design guidelines:

- Make the automation-generated solutions transparent to the controller.
- Balance automation transparency with providing only the right amount of information. A design philosophy strictly based on transparency can easily degrade into a platform that reveals too many algorithmic details about the automated recommendation.
- Promote an intuitive, direct mechanism for the controller to communicate with the automation.
- Minimize the number of hidden commands and features of the graphical user interface.

The ATC prototype is composed of a primary and a secondary display, which are both controlled via direct manipulation through a touch screen. The primary display provides visualization of real-time surveillance information in the controller's assigned airspace. The secondary display allows the controller to view the expected outcome of the automation solution. The controller uses a slider bar at bottom of the screen to explore the time dimension of this prediction.

We are now evaluating this concept through experimentation in MITRE's ATM laboratory.



SECONDARY DISPLAY PRIMARY DISPLAY

NextGen ATC Display Concepts

Flight Option Generation

The NextGen concept relies on the idea of TBO. With TBO, individual flight trajectories are rapidly replanned or renegotiated to respond to weather hazards, constrained airports or airspace resources, or air-to-air conflicts. This must be done in the presence of uncertain predictions and changing conditions. Automation is needed to do this rapidly and well.

There are many possible options for replanning flight trajectories. These include ground delays, reroutes, altitude constraints, and time constraints on specific trajectory points. But choosing efficient and operationally-acceptable flight options for TBO is a daunting problem. Today's systems depend on databases of operationally-acceptable routes to develop options, but this approach is not easily adapted to the dynamic NextGen environment. These routes were defined for moving flows rather than individual flights, and give no guidance for altitude or time-based options. More flexible option generation is needed to support TBO.

The Flight Option Generator (FOG) addresses this need. FOG has two primary functions. The first generates a set of feasible flight options, constrained by aircraft performance and any additional factors provided by the human or automation system using the FOG. The second evaluates feasible options against a wide variety of efficiency and operational metrics, including: imposed operating cost, severe weather proximity, induced air traffic control complexity, sector congestion, coordination workload, and others.

These functions provide two major benefits. First, the FOG user will be able to quickly identify desirable flight options, consistent with the dynamic operational situation. Second, the quantitative option metrics will provide a basis for negotiation between the FAA and aircraft operators, so that both traffic management and operator business objectives can be effectively met.

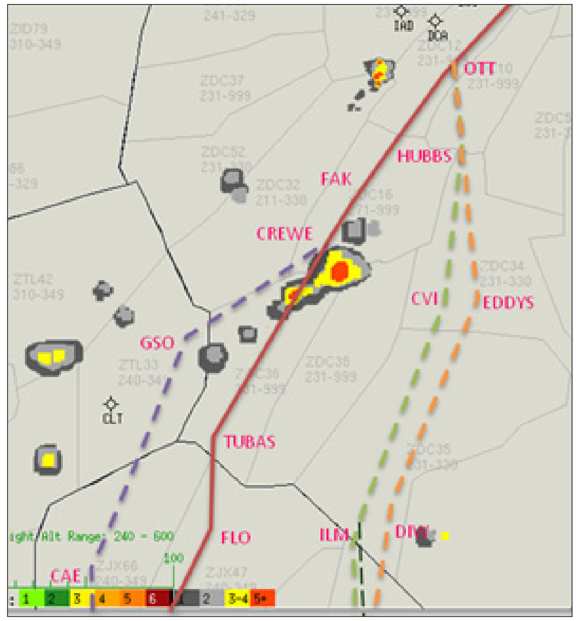
The FOG is being developed in two stages. The first will support prototyping for NextGen traffic management systems aimed at the 2011 to 2015 timeframe. The second stage aims to support studies of the complete TBO concept, including trajectory negotiation between the FAA and aircraft operators. This capability is planned for evaluation in the summer of 2010.

A great deal of progress has been made on the first stage in 2009. Work was done in three areas: option evaluation metrics, route generation methods, and preparation for human-in-the-loop evaluations to be conducted in 2010.

Option evaluation metrics were developed based on a literature review, interviews with former FAA traffic managers and controllers, and knowledge of what data is available. Twenty-three different metrics were considered, and detailed mathematical models were constructed for four of them: flow conformity factor, lateral deviation from intended route, airline costs, and potential convective weather blockage. A conference paper was published describing these in some detail [1].

Two route generation methods were developed, implemented, and integrated into a CAASD decision support prototype: the En route Flow Planning Tool (EFPT). EFPT allows traffic managers to easily identify flights that are likely to be blocked by severe weather, and suggests weather-free reroutes. With FOG integrated, many more route suggestions are available, and these suggestions come with additional metrics indicating their acceptability to controllers and impact on aircraft operators. This allows the traffic manager to develop good solutions quickly.

These algorithms were also evaluated analytically, leading to another conference paper [2]. The generated routes differ based on which option evaluation metrics are considered, so this is an important design parameter. One important tradeoff is between routes which conform well to standard flow patterns – an important factor to air traffic controllers using today's tools – and routes which incur the least cost to the aircraft operator. Thus, depending on the operational concept being evaluated (today's system vs. NextGen in 2025, for example) different metric weightings may be appropriate. Good weights have been determined for today's system, and will be used in the EFPT prototype.



Finding route options to avoid weather. The purple route at left is shorter than the original route (in red), but requires coordination with another facility. The green and orange routes are slightly longer possibilities, though it is riskier to pass in front of this eastward-moving storm than behind it. An alternative is to delay departure until the storm is predicted to have passed the original route.

In 2010 we plan to extend this work in several ways. First, the initial metrics set will be extended to capture more factors and to be more sensitive to dynamically changing conditions. For example, we would like to generate routes that conform to traffic flows being used on the day of operation, as well as being consistent with overall historical traffic patterns where possible. Second, we will extend the option generation algorithms to go beyond reroutes, considering altitude maneuvers and time constraints. And lastly, we will integrate and test the FOG with a more advanced decision support prototype that develops complete congestion solutions.

The FOG will provide a powerful enabling technology for a variety of proposed NextGen applications. An accepted method for generating and evaluating TBO options will accelerate concept development, prototyping, and deployment of practical NextGen capabilities.

1 *DeArmon, J., Nardelli, J., and Wanke, C., "Quantifying Desirable Air Route Attributes for a Reroute Generation Capability," AIAA Aircraft Technology, Integration, and Operations Conference, Hilton Head, SC, September 2009.*

2 *Taylor, C., and Wanke, C., "Dynamic Generation of Operationally Acceptable Reroutes," AIAA Aircraft Technology, Integration, and Operations Conference, Hilton Head, SC, September 2009.*

Regular Operations of UAS in Civil Airspace
Outcome 2a: UAS Sense-and-Avoid

These research activities are aimed at achieving the research outcome of developing and maturing alternative UAS sense-and-avoid solutions, evaluating and demonstrating their effectiveness, and assessing their economic viability to inform policy decisions.

Investigating Ground-Based Sense-and-Avoid for UAS Airspace Integration

Routine operation of Unmanned Aircraft Systems in unrestricted civil airspace is a high priority for a number of Department of Defense (DoD) and Department of Homeland Security (DHS) entities. Achieving this goal requires a solution that provides a UAS flight crew with traffic awareness of the airspace surrounding the unmanned aircraft and allows those personnel to maintain safe separation from all other air traffic.

This project investigates a Ground-Based Sense-and-Avoid (GBSAA) methodology for ensuring separation and achieving regular, approvable UAS operations in civil airspace. Since GBSAA is based on proven technologies, it is generally seen as a near-term option for integrating UAS into civil airspace. However, research in this area is quite limited, and only a few locations are currently close to performing a basic version of GBSAA in unrestricted airspace.

The initial objective is to assess the numerous interrelated elements of the GBSAA concept of operations interrelated elements with particular emphasis on factors such as separation strategy, procedures, crew responsibilities, and human interfaces with the decision support system. An ability to determine how to define these factors for a given unmanned platform, airspace of interest, and sensor installation will benefit users who are developing safety cases and advancing UAS integration in the NAS.

Human-In-The-Loop (HITL) simulation will be used to evaluate a variety of concepts in a controlled environment. While focusing on various traffic display and procedural concepts, effectiveness will be measured by crew workload level and margin of separation from traffic encountered. These metrics are not only critical elements of GBSAA safety cases, but also are useful for gauging the impact of future GBSAA enhancements.

The results of this initiative will include a description of separation procedures that demonstrate a manageable flight crew workload, and a traffic display concept that facilitates the safety of UAS operations. These findings will be useful for any potential future user of GBSAA and will demonstrate additional research avenues for the UAS community.

GBSAA will be key to achieving near-term access to civil airspace for many UAS operators. Investigating and evaluating all aspects of GBSAA will strengthen the safety case for routine airspace integration. Enabling the UAS community to achieve this goal in an expedient manner will benefit many stated national security objectives and also lead to a proliferation of safe UAS applications.

Cooperative Autonomous Separation Assurance for Small UAS

Forecasts of UAS activity show dramatic increases in their utilization in the NAS over the next 25 years. Preliminary steps taken by the FAA and users to integrate UAS and manned aircraft through a special waiver process have been successful in maintaining a high level of safety. The expected increases in the number of both manned and unmanned aircraft in the NextGen timeframe suggests that seamless operation and integration of UAS and other aircraft within all domains of the NAS is a functional requirement which must be addressed.

The objective of this research is to demonstrate the feasibility of small, lightweight UAS conducting cooperative autonomous traffic avoidance. This concept envisions small, lightweight (under 55 pounds) UAS equipped with compact, rugged systems designed to provide positive, timely, efficient adjustment of trajectory to avoid appropriately equipped manned aircraft, and then to efficiently return to mission profile without required intervention from the ground station or other control facility. While larger UAS with performance envelopes closer to manned aircraft are likely to adopt traffic avoidance schemes based on the existing right of way rules, emerging concepts in integration of small UAS envision a simpler set of avoidance maneuvers autonomously executed early enough in the encounter to avoid the creation of a collision avoidance situation. The concept of placing the burden of avoidance on what will likely be the smaller, more maneuverable, more difficult-to-see lightweight unmanned system is in line with emerging policy, and is supported by currently available technologies such as ADS-B, Global Positioning System (GPS)/Wide Area Augmentation System (WAAS), Universal Access Transceiver (UAT) Beacon Radio (UBR) and low cost, small, light weight computing resources suitable for use aboard small UAS.

Flight demonstrations will be used to demonstrate to stakeholders how readily available technologies may be integrated to provide lightweight, low-cost, affordable cooperative, autonomous separation assurance.

Exploration of Algorithms for the NextGen Collision Avoidance System

As the aviation community moves toward NextGen, current airborne collision avoidance technology may become inadequate. The Traffic Alert and Collision Avoidance System (TCAS) was developed some time ago, and its ability to accommodate the air-to-air applications and air traffic control procedures envisioned for NextGen is limited. In light of this, and future NextGen technologies such as ADS-B, there is a need to analyze the overall collision avoidance concept and architecture for the future.

Our objective is to answer three fundamental research questions:

- Which desired NextGen collision alerting and avoidance capabilities are not met by the current TCAS architecture?
- What new enabling technologies and design principles could meet these NextGen needs?
- What are the key functional needs that ensure enhancements and modifications do not detract from safety, which is the primary function of the collision avoidance system?

During the initial phase of this research, we identified the capabilities needed to accommodate the evolving NextGen Air Transportation System. We determined areas where TCAS does and does not satisfy those capabilities, and identified enabling technologies and associated issues.

Currently we are establishing the performance baseline for TCAS in today's environment using new metrics for assessment of detection and avoidance algorithms. We are also developing new

ADS-B-based detection and avoidance algorithms, and we are developing simulations to evaluate their performance relative to the current TCAS standard.

The aviation community's existing collision avoidance system, TCAS, which can trace its origins to the MITRE Innovation Program, has had a broad positive impact on the safety of modern aviation. MITRE has the opportunity to make a similar impact on the future by seizing the initiative to explore an integrated airborne collision alerting and avoidance system that accommodates the new applications and procedures envisioned for NextGen.

Regular Operations of UAS in Civil Airspace

Outcome 2b: Loss of C2 Link

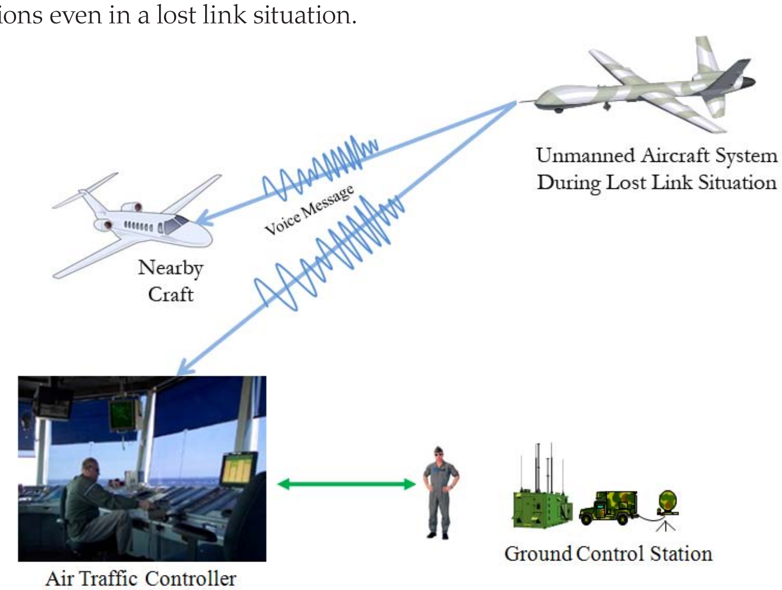
These research activities are aimed at achieving the research outcome of identifying specific operational challenges surrounding UAS C2 failure, proposing alternative solutions, and demonstrating their technical feasibility and operational effectiveness.

Intelligent UAS Situation Awareness and Information Delivery

In a scenario where a UAS has lost its command and control data link and is flying autonomously, surrounding pilots and air traffic controllers may be unaware of the flight intent of the aircraft, which will typically be pre-programmed to follow some prescribed directions in such a situation. This can make it difficult for controllers to predict where the UAS is going and to clear traffic along its intended course. The goal of this research is to investigate more robust methods for maintaining situational awareness in such a lost link scenario.

We are developing an onboard Information Analyzer to monitor the state of the UAS and determine when a lost link situation occurs. When it does, the Analyzer will interpret and convert the mission plan intent data to a standardized voice message and transmit it as Very High Frequency (VHF). Voice transmission will occur on emergency channels 121.5 MHz or 243.0 MHz, which are internationally recognized as aircraft emergency frequencies and are monitored by air traffic control, flight service stations, Air Route Traffic Control Centers, and airline operations centers. This will provide the needed situational awareness to ground personnel and surrounding pilots, and allow for safe response to the situation. In future research we will investigate the possibility of making this a two-way voice dialog by incorporating voice recognition of air traffic controller communications.

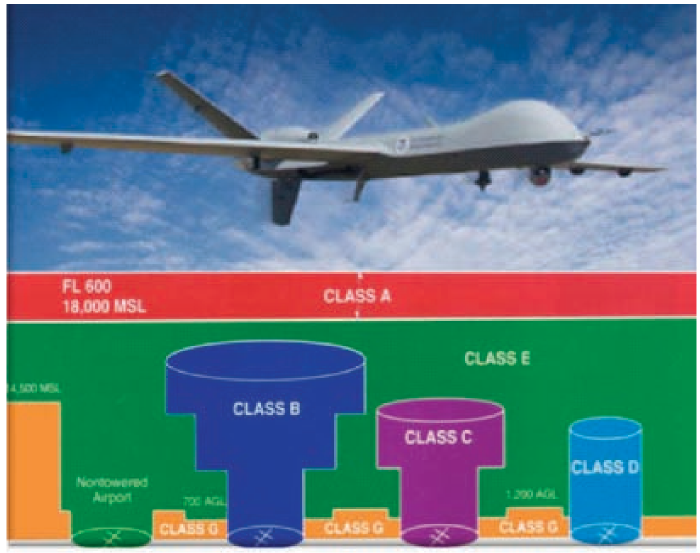
Safety concerns surrounding this lost link scenario are currently a significant impediment to allowing regular operations of UAS in the NAS. If successful, this research will identify a mechanism for ensuring safe operations even in a lost link situation.



UAS Voice Broadcast in Lost Link Situation

Implications of UAS Operations in Controlled Airspace

Demand for UAS access to the NAS is increasing, however, unmanned aircraft have several unique operational characteristics that could have an impact on ATM tasks and work load. For example, UAS cruise at a lower speed than typical transport category aircraft. This project will study how UAS currently use Class A airspace (18,000 feet and above) and will identify issues of concern to air traffic controllers. It will investigate high priority issues via HITL simulation in MITRE's ATM laboratory.



Airspace Definitions

The goal of this research is to begin to quantify human factors issues associated with UAS operations in the NAS from an air traffic control perspective. These data will be used to support the development of an analytic foundation for future FAA policy decisions. The ultimate goal of this research is to help identify ways to improve UAS access to the NAS without negatively impacting safety or efficiency.

The research began with a study of current operations of UAS through site visits and discussions with subject matter experts. The information gathered was used to develop a HITL simulation, the results from which are being used to develop a second simulation to focus on a lost command and control link scenario. In addition to the simulations, an online survey was developed to collect human factors issues associated with UAS operations in Class A airspace from an air traffic controller perspective.

This study will provide MITRE and the UAS community with critical data that can support the development of an analytic foundation to help address the potential need for UAS-specific procedures. The research will also help identify the characteristics of UAS that make their operation in Class A airspace, and more importantly their interaction with controllers, unique. This will pave the way for developing operational requirements and procedures that will allow UAS increased access to the NAS in a safe, efficient, and equitable manner.

Assurance for NextGen Software Intensive Systems

NextGen is expected to rely heavily on software-intensive systems for automated decision support. Certifying that these systems perform reliably and as expected is a significant challenge. Research is needed to identify new approaches to software assurance for these systems. The goal of this project is to develop standardized notation, tools, techniques, and patterns useful for the analysis of dependability cases for NextGen and for safety-critical software-intensive systems of systems in general.

Our first goal was to establish an initial choice of notation and techniques for incorporating an existing dependability case into tool-supported online format and for analyzing the dependability case. We then applied these tools and techniques to a specific subset of the dependability claims that we used as a case study, and calibrated what was effective. Subsequently, we extended a commercial safety case management tool to support these notations and techniques.

We defined the initial schema and plug-in framework for dependability case translation and analysis. We have established a collaborative relationship with university researchers studying dependable systems, government researchers examining safety-critical avionics, and related standards activities in RTCA and the International Organization for Standardization. We are exploring claims, arguments, and evidence patterns from a variety of sources, including assurance case best practices, hazard and risk analysis, critical software verification, and autonomous software design and development.

This research is using the Claims-Argument-Evidence assurance case notation to capture a structured inventory of consensus on how to provide assurance for autonomous systems. Some of the aspects being addressed include impacts on software assurance of delegating decision making to software, additional assurance activities required for highly autonomous systems, and identification of gaps that should be part MITRE's future research agenda for autonomous systems assurance.

Building Stakeholder Consensus
Outcome 3a: Modeling and Simulation (M&S) Tools

These research activities are aimed at achieving the research outcome of building HITL simulations and analytical models to "bring NextGen alive" in a realistic simulation environment, and expanding the range of stakeholders whose concerns are quantitatively addressed.

System-Wide Modeling for NextGen

MITRE uses fast-time simulation to understand the aggregate and network operational performance effects of NextGen improvements. Our current model of NAS operations is MITRE's *systemwide*Modeler tool. Analysts typically use the simulation to model the plans and progress of 60,000-100,000 flights as they use 50-100 airports, several hundred en route sectors, and many other elements of the NAS.

The input to *systemwide*Modeler includes descriptions of individual flights and their plans and background information about airports, airspace, fixes, etc. In addition, analysts parameterize the model's resources: the components that describe how congestion occurs and how the system responds to it. Automated facilities exist to allow analysts to construct the input for hundreds of scenarios in several hours.

The simulation's output is a database of events detailing the interactions of flights and resources. Analysts access these events through a growing number of analysis and visualization tools to measure and otherwise evaluate the behavior of the simulated NAS.

The *systemwide*Modeler tool has been used by a number of teams both to estimate the delay effects of operational improvements and to identify current and future areas of congestion. Some notable applications include NextGen Implementation Plan benefits, data communication Segment 1 benefits and the Future Airspace Capacity and Efficiency Study.

One purpose of this research is to improve *systemwide*Modeler and its sensitivity to new concepts. Modeling and software development activities are enhancing the model's representation of local congestion at airports and in airspace and the strategic management of traffic by flow managers and airspace users.

In 2010, we are introducing features that better model where flights are delayed due to congestion. One example is merging and spacing for arrival flows that captures the difference between distance-based and time-based traffic management. The model also pushes delay due to en route congestion further upstream of busy sectors when appropriate.

Adaptive Scenario Generation for NextGen Modeling and Simulation

Changes to airspace in the NextGen timeframe, including the removal of restrictions or improved precision in congestion forecasting, can be expected to lead to operators requesting different initial flight plans. Yet to this day, simulations of NextGen systems and concepts either 1) invoke a traditional approach of replicating currently observed patterns, 2) seek optimal behavior in accordance with postulated airline operations, or 3) require direct involvement of decision makers. While the first case does not capture operator adaptation, modelers of the second case rarely have access to proprietary airline operational data. The third category is generally not scalable to NAS-wide simulations of multiple NextGen alternatives.

This research project seeks to address the limitations of the second approach by applying optimal parameter estimation techniques to estimate unknown parameters and objective functions. The method does not expect to characterize every flight correctly; rather it seeks to obtain a statistical distribution of these inputs that can then be sampled to develop a scenario using an optimal flight planning approach. A comparison between approaches will be applied to determine whether NAS-wide simulations using these optimization methods have results closer to those observed with actual data versus a traditional cloning approach.

This research project uses a nested optimization approach by first determining optimal flight plans using a parameterized objective function. The objective functions and parameters are subject to an outer optimization to estimate "for what objective function is the observed flight plan an optimum?" Computational intensity is addressed through the implementation of parallelized genetic algorithms using MITRE's unified search framework.

This research will address the question, "Can an optimization approach with estimated parameters improve on scenario generation given system changes?" Expected products from this research include improved aircraft performance data (more suitable for optimization), software for optimized generation of flight plans with adjustable objective functions, and software to estimate flight planning objective function parameters.

Fast-Time Architectures for NextGen M&S

Through a continuing series of strategic investments over the past 20 years, MITRE has developed a robust collection of analytical and HITL M&S capabilities for NAS applications. But new missions present new challenges. In particular, the design, implementation and evaluation of NextGen promises to tax the current limits of CAASD's state-of-the-art modeling and simulation portfolio. In the future MITRE's needs will include the representation of emerging concepts, increased modeling scale and fidelity, and decreased turnaround times for analyses and experimentation.

Coincident with the operational challenges posed by NextGen, the computing industry is in transition – moving toward an era where concurrent applications will be the norm. Driving this transition are the emergence of the multi-core Central Processing Unit (CPU) technology, and the resurgence of long-standing concepts in grid and utility computing, now rebranded under the broad category of "cloud computing."

The distributed computing techniques necessary to deal with the shift to these new computing environments are available today. Parallel Discrete Event Simulation (PDES), in particular, is a very well-studied technique. To date, however, parallel programming in general, and PDES in particular, have largely been techniques developed by experts, for use by experts.

The objective of this research is to take a fresh look at the application of PDES technologies within the NextGen simulation environment, and to develop and evaluate frameworks for NAS modeling and simulation that can easily and effectively exploit parallel and distributed computing resources. We will define and implement our frameworks within the context of the broader NextGen fast-time M&S strategic needs, and emerging MITRE enterprise solutions for scenario generation and visualization. Currently this research is focused on three primary activities:

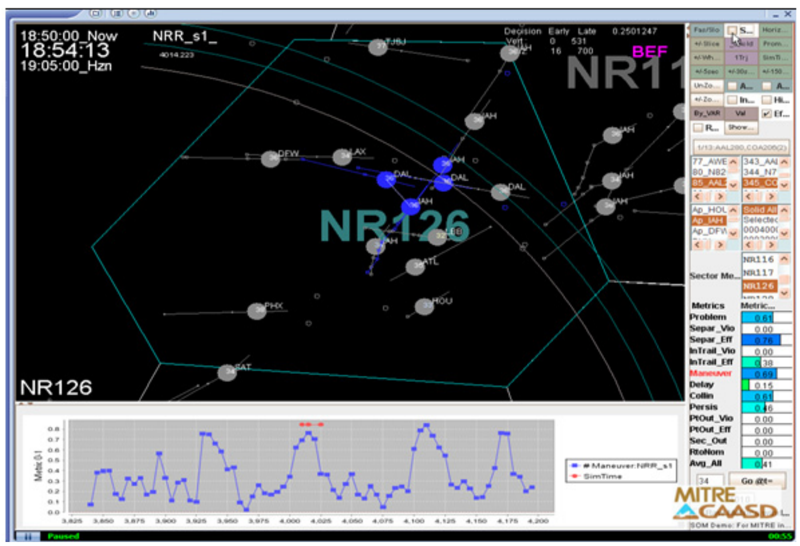
We will develop a multi-processor-based execution framework to support the entire range of NextGen fast-time simulations (which may be sequential or parallel). The framework will support parallel execution of parallel simulations, and will provide automated assistance for the scheduling and execution of replications of sequential simulations across multiple CPUs. Replication management will be facilitated by a simulation-based optimization utility: the MITRE search framework.

We will develop an intrinsically parallel architecture for a system-wide model of the NAS. We will incorporate the functionality of CAASD's *systemwide*Modeler, and provide extensibility to address anticipated NextGen system-wide analyses. The new simulation will be based on Rensselaer Optimistic Simulation System (ROSS), an open-source, high-performance parallel simulation framework.

We will seek to insulate the NAS modeler from the complexities of ROSS by: (1) developing new capabilities within ROSS, (e.g., adding a conservative synchronization scheme to eliminate the need to develop "reverse code" for simulation processes), and (2) developing a NAS-specific programming language based on existing high-level languages or emerging multi-core-specific languages, and providing mappings into ROSS.

High Performance Automated Air Traffic Analysis

The current suite of tools used by MITRE for air traffic analysis includes our own *airspace*Analyzer working in conjunction with commercial optimization technology (e.g., IBM's ILOG CPLEX software suite). This technology is expensive and limited in the scope and scale of its use, particularly for very large problems.



Automated Air Traffic Analysis

The purpose of this work is to investigate approaches to deploying our analyses to a distributed computational environment. The benefits of doing this are two-fold: very large analyses can run much more quickly, and analyses that were previously considered to be computationally intractable can become feasible. For example, *airspace*Analyzer can currently run the non-terminal sectors of the Los Angeles ARTCC in slightly faster than real time; in contrast, executing in parallel on a computational cluster would enable real-time runs for the entire en-route segment of the NAS. This capability offers the potential to improve NAS analysis far beyond its current scope, with the promise of significantly exceeding the performance of today's implementations.

The interdisciplinary research team for this project includes MITRE experts in air traffic control, sector complexity analysis, linear programming, and high performance computing. The proposed research includes developing and deploying a novel computational approach to solving linear programming problems. This approach lends itself well to deployment on commodity cluster computing resources, and removes the need for commercial closed-source licenses.

In addition to large-scale parallelization on a commodity cluster, there are elements of the current *airspace*Analyzer pipeline that can be offloaded to commodity Graphics Processing Units (GPUs). GPUs add a fine-grained "co-processing" capability to mathematically intensive computations, and will provide additional performance gains.

When coupled with a re-factored *airspace*Analyzer, we anticipate very large performance gains from the combination of large-scale parallelization with fine-grained GPU co-processing. Ultimately, these performance gains will enable demonstrating real-time analysis of the entire NAS using a commodity computational cluster.

Visualization Service Bus

Currently aviation research visualizations are customized for each new simulation or analysis. This research seeks to develop an integrated visualization architecture that will allow analysts to rapidly and easily integrate ATM data sources, analytical results, and simulation output for use on advanced visualization displays.

The Visualization Service Bus (VSB) will provide an environment that fosters the generation of more effective visualizations from existing and new tools. We will demonstrate innovative ways to visualize data, and will develop a deployment plan to provide these capabilities to MITRE and our sponsors.

We will identify internal and external data sources and develop a visualization interface to a number of these so that users can assemble visualizations of NAS data. We will identify MITRE projects that could benefit from such an environment and work to tailor this environment to their needs. We will also develop a deployment strategy to expose this interface more broadly to the research community.

This architecture will enable users to develop and tailor visualizations to their specific needs. This should lead to improvements by MITRE staff in the use of visual techniques for communicating results, both internally and to sponsor and stakeholder communities. Through this research we also expect to gain insight into advanced service-oriented architecture technologies and their application.

Visualization Service Bus Graphical User Interface

Building Stakeholder Consensus

Outcome 3b: Connecting Stakeholder Communities

These research activities are aimed at achieving the research outcome of connecting stakeholder communities through integrated modeling and simulation environments and improving mutual comprehension.

NextGen Interagency Experimentation Hub

The Joint Planning and Development Office envisions a comprehensive, coordinated set of experimentation activities to investigate emerging concepts with its DHS, DoD, DOT, FAA, and other mission partners. To achieve this vision, the JPDO will need help composing the necessary distributed, operator-in-the-loop computing environments. MITRE is well suited to provide both the interagency expertise and computing assets to form a hub for these activities.

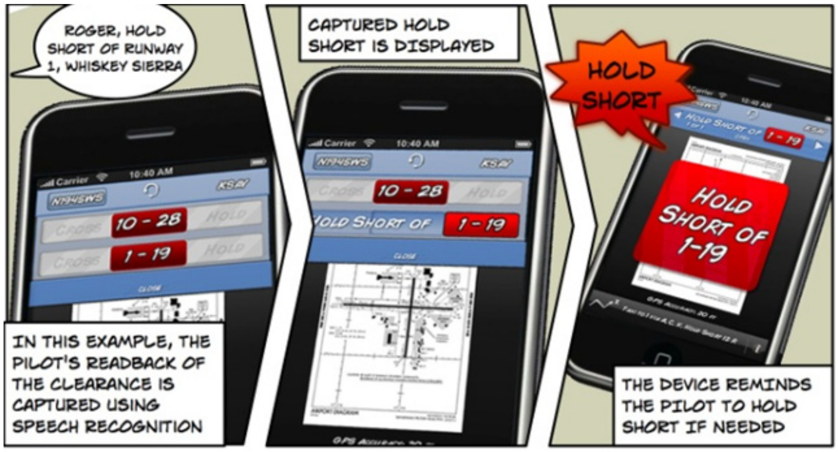
This research effort is examining cross-boundary information sharing technologies, determining their applicability for the NextGen interagency experimentation mission space, and developing connectivity solutions for selected cross-boundary venues. Initially, we documented experimentation use cases that require cross-domain and cross-firewall data flows for proper interagency participation. This research has now begun evaluating the merits of a set of these cross-boundary data flows in a distributed, unclassified test bed. This test bed includes (1) aviation simulations and operator stations in the MITRE ATM Lab, (2) cross-boundary solutions such as SimShield™, Radiant Mercury, and AviationSimNet® in MITRE's Cross-Boundary Information Sharing (XBIS) Lab, and (3) representative NextGen partner agency stations in MITRE's Simulation Interoperability Facility (SIF) Lab.

Based on lessons learned from this unclassified test bed work, we will implement cross-boundary solutions for specific experimentation programs.

Low Cost Runway Incursion Prevention

In literally 99.995 percent of taxi operations, after correctly reading back a taxi clearance, the pilot proceeds to the runway without incident. However, about once every 20,000 operations something goes awry and the result is a Runway Incursion (RI). In a typical year there are about 350 runway incursions.

Incursions remain a serious concern in aviation safety; tools and techniques for RI prevention have been on the National Transportation Safety Board's list of most wanted safety improvements since its inception. In fact, the worst accident in aviation history (a collision on the runway at Tenerife airport) was the result of a runway incursion. In about 55 percent of all runway incursions, the pilot correctly



reads back the hold short clearance as given by the controller but then proceeds through the hold line without stopping. This type of incursion—the pilot deviation—has three common causes including: a lost pilot, a distracted pilot, and a pilot who forgets or misremembers the taxiway clearance.

A lot of technology has been built to address the runway incursion problem including the Runway Awareness Advisory System, surface moving maps, Airport Surface Detection Equipment Model X (ASDE-X) safety logic, and Runway Status Lights. While effective where employed, these solutions are also typically very expensive. That expense comes with a cost—a loss in coverage. As the expense of a technology increases, the General Aviation (GA) access to that technology generally decreases. The loss of GA coverage is important because GA aircraft are involved in 75 percent of all runway incursions and in 82 percent of all pilot deviations. To provide better RI prevention coverage for the GA population, we need a low-cost solution that's not dependent on airport infrastructure. Furthermore, in order to provide protection from all three common causes of pilot deviations, that solution needs to be able to capture the taxi clearance.

As it turns out, GPS-enabled handheld personal digital assistant devices may be an excellent platform for a low-cost incursion prevention system. The devices are often already owned by the pilot and deployment of applications for these systems is relatively inexpensive. GPS insures that the pilot is not dependent on airport infrastructure and all of these devices provide a variety of ways to input the taxi clearance. Our research is investigating the technical and procedural feasibility of using handheld devices in this manner.

As the pilot and controller communicate with each other, the device listens for hold short instructions. The hold short instructions the device "heard" (via speech recognition) are then presented on the display. What does the device do? Most of the time it does absolutely nothing. If the algorithm predicts the aircraft will hold short of the runway it provides no reminders. Therefore, the device does not give indiscriminate warnings and largely remains transparent to the pilot. On the other hand, if, after being instructed to hold short, it looks like the pilot is not going to stop the device will provide a visual and aural reminder.

The initial plan is to work solely on protecting the runway. However, if that research is successful, we may look at providing additional information to the pilot, such as the taxi path.

NextGen Stakeholder Valuation

"Making predictions is hard, especially about the future," observed Yogi Berra. Making predictions about the behavior of a highly complex system-of-systems with poorly understood emergent behavior such as NextGen is all the more so.

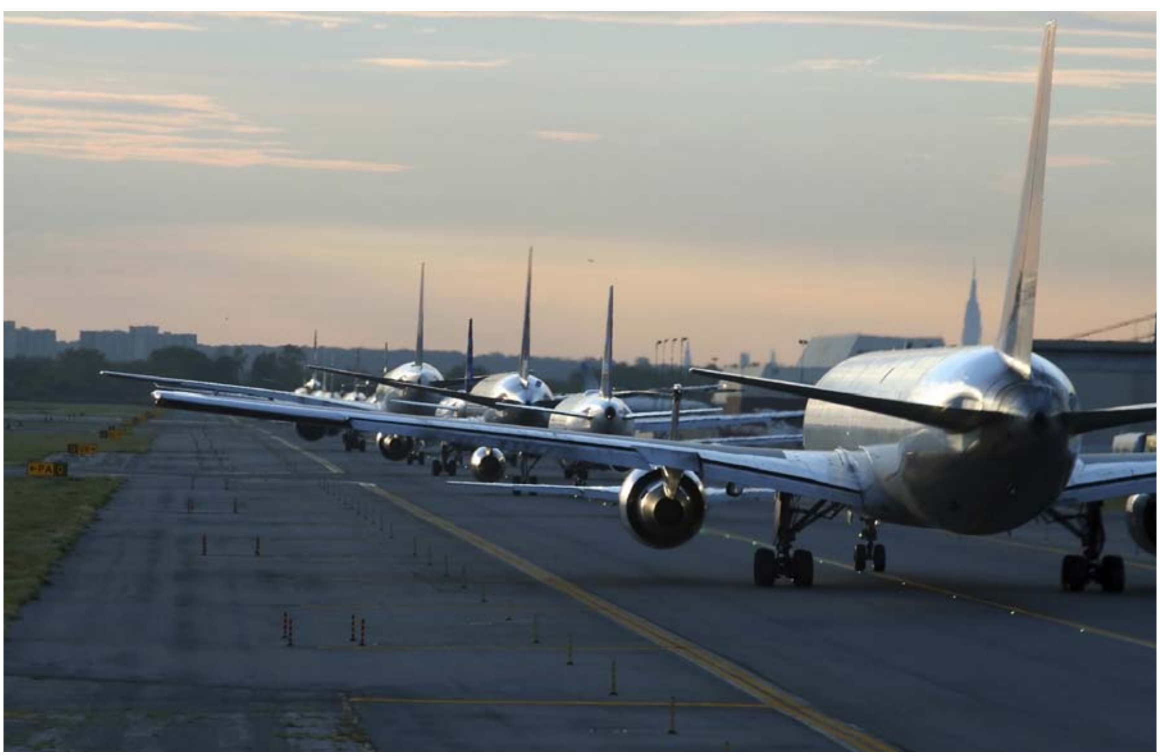
Decision makers in the aviation community must assess the business case implications of major portfolio investments. Since progress in aviation modernization requires coordinated action across multiple stakeholder groups, a common means for evaluating business case implications of new operational concepts, technology insertion opportunities, alternate business models, and policy initiatives is needed.

The goals of this research are to develop a set of analytical tools for business case analysis and to exercise these tools across a set of NextGen investment decisions to evaluate the business implications of alternate policy, operational, and technical approaches to aviation modernization.

A tool set has been developed using the Analytica® software platform. The model structure permits evaluation of alternate configurations of capabilities. For example, the results of discrete operational effect simulations can be integrated to realize a meta-model of operational behavior in the NAS that has not been otherwise evaluated directly. This approach permits the joint analysis of cash flows and economic results to allow stakeholders to visualize the impact of investment decision alternatives on their own institutions and others. By providing an agile means of assessing alternate portfolio configurations this capability prepares decision-makers to engage one another through constructive, data-driven discussions.

Throughput and Delay Under NextGen

Approximately 70 percent of air traffic delays in the U.S. are caused by weather. If we could eliminate the impact of weather on airline operations, would delays decrease? At the heart of this seemingly peculiar question is the tradeoff between reduced delay and increased throughput. Whether an increase in capacity is incorporated into the air transportation system through reduced delay or increased throughput is largely determined by the response of airlines and other users.



As is the standard approach in cost-benefit analysis, the benefits estimates for NextGen generally assume that increased capacity results in reduced delay. The implicit assumption is that the value of the reduced delay is a reasonable proxy for the value of the more likely combination of reduced delay and increased throughput, so the result of the cost-benefit analysis is still valid. This approach is taken because of the difficulty of estimating the dynamic response of users to an improvement in the system.

But does this standard approach sufficiently inform the decisions needed to implement NextGen? NextGen is a complex portfolio of programs that has been presented as a solution to chronic delay, but as currently configured NextGen has a limited ability to influence the resulting balance between delay and throughput. This balance matters. Public complaints and congressional hearings focus on excessive delays, not on a lack of throughput. By one measure, throughput has roughly doubled since 1987 and tripled since 1982, but current delays are still considered unacceptable.

A related issue is the benefit of increased predictability which is expected to result from NextGen. The benefit of increased predictability is commonly assumed to be captured by reduced delay under the standard benefit-estimation approach. While this is reasonable in some cases, NextGen is expected to have a large impact on predictability, so there is a need to be sure that we properly capture those benefits.

This research will explore four issues:

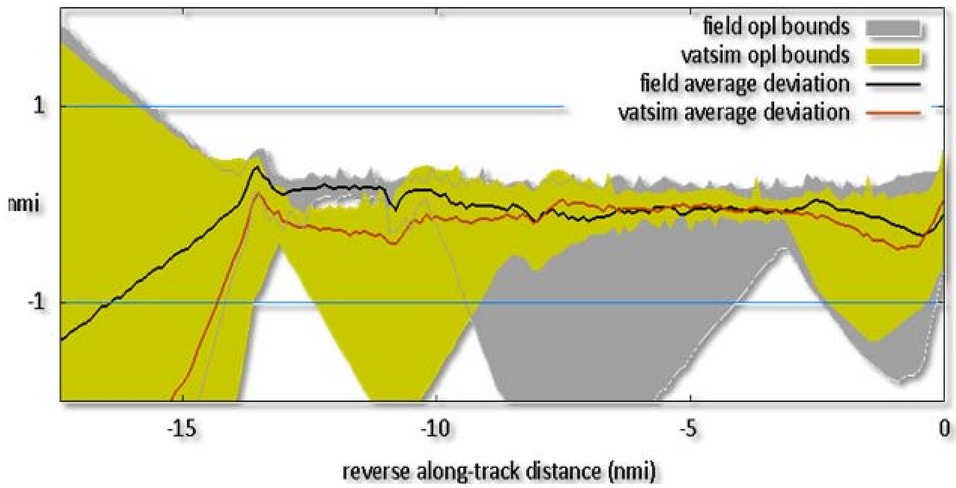
- How do our current modeling and simulation capabilities address the trade-off between delay and throughput?
- Could those capabilities be used to illustrate the implications of the trade-off for NextGen?
- How do our current modeling and simulation capabilities address the impact of improved predictability?
- Are there additional benefits of improved predictability that are not capture by changes in delay and throughput?

Virtual Air Traffic Simulation Capability

VATSIM, the Virtual Air Traffic Simulation environment, is a worldwide online community of aviation enthusiasts and experts who use a combination of commercial and custom-built software to run a real-time, Internet-based simulation of the global aviation environment. Membership in the VATSIM network numbers about 100,000 with about 2,000 regular players who participate either as pilots or air traffic controllers. We are examining the suitability of this community for performing aviation research on future NextGen concepts. Three alternative approaches are being explored.

The first approach uses the existing VATSIM network and community, in an "as-is" configuration, to directly perform experiments. Using this approach, the VATSIM team can host organized simulation "events" where users are invited to participate in exploring a particular concept. To date we have hosted three such events, respectively examining: new approach procedures into Chicago O'Hare airport, conformance with RNAV procedures at Las Vegas McCarran airport, and an Optimized Profile Descent procedure into Atlanta Hartsfield airport. While hosting these simulations directly in VATSIM gives the underlying concepts wide audience exposure, it only allows us to implement very limited control of critical elements of the experiment.

The second approach we evaluated is to "push" a controlled experiment onto the desktop of each participant. This allows us to tap into the large network of VATSIM members but in a more controlled



GRNPA1-Average and Bounding Tracks: VATSIM vs. Field Data for the Same Day

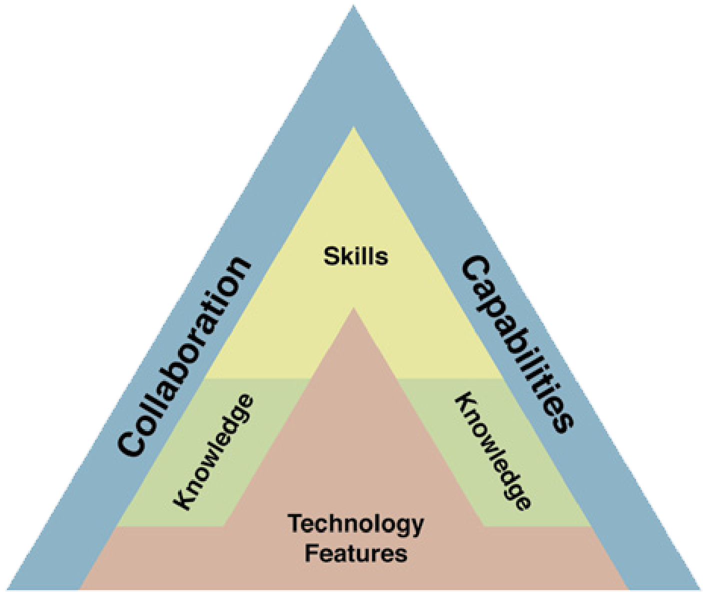
fashion. Subjects need only download and install a pre-configured mission file, created by MITRE, on their existing flight simulator, and fly the predefined "missions" which replicate precise traffic scenarios. Results are then fed back to MITRE for analysis. This approach provides a higher degree of control over the "aviation problem" than the previous approach.

The third approach is to make MITRE's ATM laboratory interoperate with VATSIM. This important capability allows us to create a more controlled environment on the VATSIM side, and potentially brings a large number of pilot subjects and their high fidelity Flight Management Computers (FMCs) into MITRE's experimentation environment. This combination of human pilots in high fidelity cockpits equipped with FMCs is highly desirable. This year we completed and documented the software bridge capabilities that enable this kind of experimentation, and have planned two experiments involving UAS operations.

Our goal is to assess the research value of each of these modes of operations and compare results against our existing baselines in MITRE's ATM laboratory. In addition, this capability allows us to expose MITRE's researchers to a new community and to engage this community to gain insight into proposed new concepts, technologies and procedures in the NextGen timeframe. We are developing criteria to help MITRE research staff understand the suitability of VATSIM for a particular purpose as well as practices for participation in a massively multiplayer online role-playing game. These practices include guidelines for enlisting participants, distributing software, understanding their strengths and weaknesses, and data collection.

Aviation Security Collaboration

Collaboration on national airspace security requires tightly orchestrated activities across a number of organizations in diverse locations. Today this coordination takes place through voice conferencing over the FAA's Domestic Events Network. The JPDO's Security Annex Concept of Operations for NextGen recommends "a unified command, control, and communication framework for integrated risk management decision-making." Although there has been considerable research to date in areas related to the collaboration required for such a unified framework, until this study no research has combined the multiple characteristics of synchronicity, non-collocation, multiple organizations, time sensitivity,



Avation Security Collaboration Framework

and crisis management in the aviation domain. This study of procedures and technology features is intended to improve the timeliness and effectiveness of this multi-agency collaboration on national airspace security.

The goal of this research is to develop a crisis management collaboration framework, to include the knowledge and collaboration skills necessary for inter-organizational crisis management participants and a basic set of technology features that support these skills, and to validate elements of this framework in a laboratory environment. The research team has identified13 collaboration capabilities needed to support the stakeholder security partners in their mission. The capabilities are organized within our Crisis Management Collaboration Framework in three groups: getting and sharing information, understanding information, and coordinating operations.

Systems are a collection of people, processes, and automation. The framework describes how the collaboration capabilities are supported by three sets of collaboration elements: knowledge (people), skills (people performing processes), and technology features (automation). People's knowledge supports their skills, and technology features support both knowledge and skills. The collaboration framework identifies which knowledge, skills, and technology features are critical, important, or indirectly helpful in achieving each of the 13 collaboration capabilities. This will enable stakeholders to choose where to concentrate their resources to support those collaboration capabilities most important to them.

While developed for the aviation security community, this framework should be useful to other domains that experience cross-organizational, time-sensitive, safety-critical collaboration, such as disaster response or joint military command and control.

Integrated Economy-Wide Modeling

Aviation is tightly connected to the broader U.S. economy. As a result, the FAA's aviation policy and investment decisions have economy-wide impact. If the aviation sector becomes more efficient, industries relying on aviation implicitly also improve efficiency. When greater efficiency means resource savings, these resources can be put to productive uses. The FAA needs to understand connections and impacts beyond the aviation industry. Of equal importance is the need to understand the economy-wide consequences of no action or delayed action in making the case for critical investments, such as NextGen.

This research is using an approach known as Computable General Equilibrium (CGE) modeling. CGE is a technique for consistently modeling economy-wide connections, to carefully identify the economic consequences of changes to one industry on other industries and the economy as a whole. This research is tailoring existing CGE modeling to the aviation domain to understand the broader economic impact of NextGen.

The project is using the U.S. Applied General Equilibrium (USAGE) model from Monash University to model the impact of NextGen on the economy relative to the "do nothing" base case. Initially an aviation-specific subset of the model, known as USAGE-Air, was used to run a series of notional representations of NextGen for the purposes of understanding the overall approach. Our current work is to apply NextGen-specific data to begin to develop a capability to analyze the impacts of NextGen policy decisions being considered by the FAA and JPDO.

The Integrated Economy-Wide Modeling research offers a new perspective in making the case for investing in NextGen by adding a dimension to its benefits not included in previous analyses. These results will help communicate the value of NextGen to the Administration and Congress. The work will also result in the ability to carry out future economy-wide studies, leveraging the understanding gained through the NextGen sample problem analysis.

Acronyms

ADS-B	Automatic Dependent Surveillance-Broadcast
ARTCC	Air Route Traffic Control Center
ASDE-X	Airport Surface Detection Equipment Model X
ATC	Air Traffic Control
ATM	Air Traffic Management
C2	Command and Control
CAASD	Center for Advanced Aviation System Development
CDTI	Cockpit Display of Traffic Information
CGE	Computable General Equilibrium
CPU	Central Processing Unit
DHS	Department of Homeland Security
DoD	Department of Defense
DOT	Department of Transportation
EFPT	En Route Flow Planning Tool
EVS	Enhanced Visions Systems
FAA	Federal Aviation Administration
FFRDC	Federally Funded Research and Development Center
FMC	Flight Management Computer
FOG	Flight Option Generator
GA	General Aviation
GBSAA	Ground-Based Sense-and-Avoid
GPS	Global Positioning System
GPU	Graphics Processing Unit
HITL	Human-In-The-Loop
IMC	Instrument Meteorological Conditions
JEDI	Java En route Development Initiative
JPDO	Joint Planning and Development Office
M&S	Modeling and Simulation
MIP	MITRE Innovation Program
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NextGen	Next Generation Air Transportation System
PDES	Parallel Discrete Event Simulation
RI	Runway Incursion
RNAV	Area Navigation
RNP	Required Navigational Performance
ROSS	Rensselaer Optimistic Simulation System
SIF	Simulation Interoperability Facility
SVS	Synthetic Vision Systems
TBO	Trajectory-Based Operations
TCAS	Traffic Alert and Collision Avoidance System
TMC	Traffic Management Coordinator
UAS	Unmanned Aircraft Systems
UAT	Universal Access Transceiver
UBR	UAT Beacon Radio
USAGE	U.S. Applied General Equilibrium model
VATSIM	Virtual Air Traffic Simulation
VHF	Very High Frequency
VSB	Visualization Service Bus
WAAS	Wide Area Augmentation System
XBIS	Cross-Boundary Information Sharing

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