The MITRE Corporation’s Center for Advanced Aviation System Development

The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) is a federally funded research and development center (FFRDC) sponsored by the Federal Aviation Administration (FAA). The MITRE Corporation, a not-for-profit national resource provides systems engineering, research and development, and information technology support to governments around the globe. MITRE/CAASD supports the FAA and other civil aviation authorities from its facilities in McLean, Virginia, about 20 minutes from Washington, D.C.

MITRE/CAASD adds value to all ATM modernization programs and helps accomplish national objectives for evolving ATM systems to be capable of handling anticipated increases in traffic and greater diversity of aircraft.

MITRE/CAASD focus areas include:

- Architecture and System Engineering
- Airport Capacity Improvements
- Advanced Decision Support Systems
- Global Communications, Navigation, and Surveillance
- Collaborative Decision Making
- Modeling, Simulation, and Advanced Development

MITRE/CAASD is committed to working in partnership with civil aviation organizations throughout the world to develop harmonized and integrated systems that promote safe and efficient global air traffic management. Our innovations in areas such as advanced automation systems for controller training, performance-based air traffic management systems for increased controller productivity and increased user benefits, conflict probe and resolution, the application of Automatic Dependent Surveillance-Broadcast, Global Positioning System modeling, the National Airspace System Report Card and other performance measuring capabilities, and the Traffic Alert and Collision Avoidance System (TCAS) have greatly influenced current trends in traffic control and management. MITRE/CAASD’s leadership on these and other projects is made possible by our unique combination of values and characteristics: an emphasis on quality, integrity, and objectivity; a long-term perspective and corporate memory; and the merging of operational, technical, and programmatic expertise.

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MITRE/CAASD carries out highly technical engineering and operational analyses, system development, and system specification activities to help the FAA and our other civil aviation sponsors around the world, to plan, develop, acquire, and implement new capabilities that modernize air traffic management (ATM) systems. With its long and distinguished history, MITRE/CAASD is able to recognize and understand the concerns of our civil aviation sponsors, especially the need for a safe and efficient ATM environment in conformance with the standards and recommended practices of the International Civil Aviation Organization (ICAO). Our analyses and recommendations carefully account for the unique circumstances that characterize each country's civil aviation posture. We can assist in the selection and implementation of the best system tailored to the local situation.
Forecasts for traffic growth in Europe and the United States over the next several decades suggest that solely improving ground systems will likely come at a high cost to achieve the required capacity and provision of services. The development of a close cooperation between ground and airborne systems, the use of new procedures, and the shifting of roles and responsibilities across system participants provide several avenues to meet this challenge. One promising option is airborne delegation—a procedure that temporarily delegates separation responsibility from ground air traffic control to the cockpit under specific conditions.

Recent research by The MITRE Corporation's Center for Advanced Aviation System Development (MITRE/CAASD) recognizes the potential value of airborne delegation as a distributed means of providing flexible alternative solutions for future National Airspace System (NAS) operations that leverages evolving avionics and surveillance technology. Concurrently, the research also recognizes the value in maintaining an overall centralized picture for efficient planning and control of operations, mainly those during peaks in traffic demand.

Similar to the current visual separation application, the Controller-Assigned Airborne Separation (CAAS) concept relies on certified airborne components aboard the maneuvering aircraft to perform "electronic" visual separation. Specifically, to achieve separation it identifies a target aircraft and generates headings. CAAS enables a controller to authorize such an equipped aircraft to achieve and maintain separation from the designated target aircraft. The delegation of responsibility is temporary and specific to the encounter. The controller would continue to provide separation from all other traffic and any other hazards. Once the flight crew accepts the CAAS-based clearance to avoid the other aircraft, they accept responsibility for separation for that operation. CAAS imposes requirements for both the airborne components and the ground-based automation system, including display inputs/outputs for both, and detailed procedures for initiating, completing, and terminating a given CAAS operation. However, the benefits potentially include a reduced tactical workload for the controller. This leads to improved system scalability and enhanced safety through increased situational awareness and direct cockpit participation in separation decisions.

Concept Exploration studies of the CAAS concept for a pairwise crossing application and more strategic airborne separation have been conducted by CAASD. Both CAAS concepts were explored in laboratory evaluations involving controller and pilot participants. While additional research remains, these early evaluations of airborne delegation concepts produced encouraging results. The concepts show promise to be both operationally feasible and to deliver benefits to the NAS.

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The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD), a federally funded research and development centers sponsored by the United States Federal Aviation Administration (FAA), has extensive experience supporting efforts throughout the global aviation community in addressing many of the issues facing the planners and designers of tomorrow’s airports. In our state-of-the-art laboratory facilities, we use modeling, simulation, and rapid prototyping to analyze problems and propose solutions to meet customer requirements.

**Airport Analysis.** We have in our laboratories sophisticated analysis tools that help airport planners and designers evaluate complicated issues. We can perform modeling analyses to study the relationships between key operations. We have the capability to design integrated processes to enhance capacity while noise is kept to a minimum and to support airport concepts of the future. We have extensive experience to support the design and evaluation of airport command and control centers. Our staff includes airport designers, air traffic controllers, pilots, and airport managers.

**Airport Capacity, Delay, and Noise Modeling.** Defining and measuring capacity is an extraordinarily complex problem because of the numerous variables involved in the process of measuring the maximum throughput of a single runway (or a runway system) at a given airport. MITRE/CAASD developed many of the models that the FAA uses today to perform these analyses. We have validated the results of our mathematical models with statistics from actual airport operations. Variables such as arriving aircraft mix, interarrival times, runway occupancy times, and the physical layout of multiple runways have been successfully included in our models.

Two basic ways to increase air traffic capacity in a metropolitan area are: the construction of new airports or new runways at existing airports and the improvement of established arrival and departure procedures. MITRE/CAASD has focused its technical resources to create methodologies that will help existing airports best utilize available resources. For example, MITRE/CAASD has developed procedures for simultaneous approaches to parallel runways that permit reduced separation between the runways without sacrificing safety. We have also developed new procedures for simultaneous approaches to converging runways and triple-parallel approaches. These capacity enhancements often minimize delay and resolve environmental issues.

MITRE/CAASD has extensive experience with the use of models that analyze and predict aircraft acoustic profiles or contours (“noise”). Our studies often include long-term acoustic contour predictions for a number of alternative air traffic demand scenarios. Furthermore, our analyses do not conclude with the evaluation of the situation. We suggest alternatives to diminish the severity of the problem. One such example was a comprehensive analysis for Aéroports de Paris (ADP) to evaluate the impact of new runway construction and future traffic at Paris Charles de Gaulle Airport.

**Conclusion.** We are qualified to support a great variety of projects, including development, operational and technical analyses, feasibility studies, and cost-benefit analyses. In addition, we can develop hardware and software specifications, perform technical evaluation of bids, and supervise project implementation. We have demonstrated our capabilities through many United States projects, including such major airports as Dallas/Fort Worth and Chicago O’Hare, and starting in the late 1950s, in over 40 nations.

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Modern, effective airspace is the foundation for modern, effective air travel. Airspace design and management are critical functions in providing a robust system that meets the demands of current and future air commerce. The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) is working with the aviation community to ensure the airspace that underlies and supports it, continues to operate at the highest levels of safety, security, and efficiency.

For the last decade, MITRE/CAASD has been a trusted partner and a key resource in many important airspace design actions. MITRE/CAASD has significant experience and expertise in all aspects of airspace modernization.

Problem Identification: The first step of any airspace redesign effort is to understand the underlying operational issues, and to determine whether these problems can be solved with airspace design. This involves using diagnostic tools to look at traffic flows, identify operational bottlenecks or chokepoints, and ascertain potential solutions. MITRE/CAASD has one of the most complete sets of data analysis tools and data for airspace elements (routes, fixes, and boundaries) and current and projected traffic.

Design and Analysis of Alternatives: A good design must balance multiple factors: flexibility, predictability, efficiency, safety, security, and the environment. MITRE/CAASD combines over one-hundred years of airspace design expertise with a unique set of tools and operational innovation to facilitate large scale design. Many recent airspace efforts have also leveraged other corporate expertise in area navigation (RNAV) and required navigation performance (RNP). MITRE/CAASD’s aligned capabilities were fundamental in the FAA’s recent successful large scale redesigns in South Florida and the Great Lakes Corridor. Other examples of MITRE/CAASD’s efforts include design and analysis of ground-breaking, integrated airspace for the New York/Philadelphia metro areas, human-in-the-loop and fast-time models of airspace benefits in Chicago, and operational and environmental analyses for the Houston area.

Implementation Engineering and Risk Mitigation: Moving from design to implementation is a large challenge. Technical, economic, and political risks are associated with every redesign effort. MITRE/CAASD capitalizes on its extensive corporate knowledge and systems engineering background in identifying issues that will challenge project viability and development of effective mitigation plans.

Post-Implementation: The airspace redesign process is not complete once a design is implemented. Sometimes a design must be revisited and adjusted, to fully achieve the expected benefits or to mitigate unforeseen negative impacts. Measuring the effectiveness of the effort is also important. MITRE/CAASD has played a major role in post-implementation efforts for several major projects, including both design alteration and impact measurements.

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Airspace design is the process of creating sector boundaries and routes to support the safe and expeditious flow of aircraft. This job has historically been performed by air traffic controllers acting as local airspace experts who identify problems, consider options, and propose solutions multiple times to refine the design. This is a mixture of art and science that has worked well in the past, however it requires significant time and staffing resources. Also, due to the interconnectedness of the national airspace system, controller solutions to local problems may have unintended effects elsewhere in the system.

To make the task of airspace redesign more efficient and able to prevent unintended effects, the Federal Aviation Administration (FAA) and The MITRE Corporation's Center for Advanced Aviation System Development (MITRE/CAASD), has developed the airspaceToolsuite. This set of tools includes three core capabilities: airspacePartitioner, airspaceAnalyzer, and the sectorEvaluator; and provides visualization and automated analytical support to airspace designers within an integrated three step process.

The first step in the process defines the airspace environment to be redesigned and partitions it into regions of equal complexity. The airspace environment is defined by traffic profiles; the communications, navigation, and surveillance environment; automation support; and Air Traffic Management resources available in the study region. MITRE/CAASD calls upon its extensive demand forecasting and flight trajectory modeling capabilities to develop airspace demand profiles for any number of different conditions or assumptions. Then, MITRE/CAASD's airspacePartitioner creates a map of geographically distributed traffic complexity (based on a specific set of metrics) for the study region and divides the airspace into areas of equal complexity. The desired amount of complexity for each partition is adjustable and can be benchmarked against one, two, or three person sectors.

In the second step, the airspaceAnalyzer, a fast-time, simulation model, identifies unmanageable airspace regions requiring further boundary analyses. The airspaceAnalyzer mimics air traffic control (ATC) by providing aircraft-to-aircraft and aircraft-to-airspace separation, and adherence to traffic flow management (TFM) and other procedural restrictions. Wherever airspaceAnalyzer is unable to perform these tasks efficiently, the airspace design must be remediated.

The final step in the design process utilizes the sectorEvaluator. This tool uses a knowledge database of design best practices captured from human airspace designers to recommend solutions to the problems identified in step three. For example, sectorEvaluator may suggest relocating a sector boundary to minimize point-outs or reduce excessive scanning.

Using objective, repeatable, and transparent methods, the airspaceToolsuite facilitates a more efficient airspace design process.

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Analyzing Current and Future National Airspace System Performance

The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD), Federal Aviation Administration’s (FAA) Federally Funded Research and Development Center, analyzes current and future demand and capacity needs for airports and airspace. In performing these analyses, MITRE/CAASD works with the FAA and aviation stakeholders and applies a wide range of simulation tools.

CAASD researchers have enhanced the state of the art in traffic-schedule demand forecasting through the inclusion of metropolitan area socio-economic modeling techniques. Using these techniques and national forecasts, CAASD produces seasonal forecasts of flights by time of day that reflects future aircraft schedules and routings. These traffic predictions are used to determine the effect of demand and capacity imbalances on key national airspace system resources, such as busy airports and congested airspace.

CAASD researchers analyze the effect of new technology and then use runwaySimulator, CAASD’s airport model to simulate and analyze the capacity at complex airports.

Similarly analysts develop inputs for CAASD’s systemwideModeler, which is a simulation model of the National Airspace System, to reflect planned enhancements to en route and terminal systems and procedures. Using these simulation models CAASD determines the effect on system performance and workload.

2015 Average Delay at OEP Airports
Incorporating the Variation in Demand Forecasts

<table>
<thead>
<tr>
<th>Good Weather</th>
<th>Bad Weather</th>
<th>Annual</th>
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<td>3.9</td>
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<td>19.0</td>
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<td>45.3</td>
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The results of these simulation models are then used in FAA decision making. These simulation models were used to project the expected benefits of the FAA Operational Evolution Plan and to identify future capacity shortfalls at major airports and metropolitan areas across the US.

Airports and Metropolitan Areas Needing Capacity in 2025 after Planned Improvements

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Since the terrorist attacks of September 11, 2001, the efforts to manage and secure the air transportation system in the United States has become progressively complex. Threats can take many forms and occur on the aircraft, in cargo areas, airports, airspace, and areas adjacent to aviation facilities as well. Providing aviation security requires a multi-layered, adaptive approach that starts with an integrated understanding of the total threat vector, followed by security of airports, people, baggage, cargo/mail, airspace, and aircraft. Over the last six years, The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) has become a close and valuable partner to the aviation security community. Working with the Joint Planning and Development Office (JPDO), MITRE/CAASD played a key role in developing a vision of aviation security for the 2025 timeframe. The JPDO’s Concept of Operations version 2.0 captures this vision.

Working with the FAA’s System Operations Security organization, MITRE/CAASD has helped to develop a concept of operations for future system capabilities to detect and respond to potential airspace security threats.

MITRE/CAASD has also partnered with the Transportation Security Administration (TSA) to provide important technical and programmatic analyses to such programs as Registered Traveler, Transportation Worker Identification Credential, Hazardous Material (HAZMAT) Driver’s Endorsement, Aviation Worker Program, and Indirect Air Carrier Program.

A strong research and development (R&D) program is essential to meeting aviation security’s future challenges. MITRE/CAASD has invested in several R&D efforts. One example, the Airspace Security Portal, integrates information surrounding a security incident with decision support tools to help users respond quickly to an incident with minimum impact on aviation operations.

Another example of MITRE’s R&D efforts is its research into airport movements modeling. This research explores the impact of threat prevention on airport operations. Integrating this model with MITRE’s Integrated Air Traffic Management Laboratory provides MITRE the ability to quickly analyze the impact of aviation security incidents on almost all aspects of the National Airspace System (NAS).

In addition, MITRE is extending this model to assess the effectiveness of an airport’s layered defenses against an active adversary.

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Widely acknowledged as an effective way to study many air traffic management (ATM) issues, real-time human-in-the-loop simulations can now be greatly enhanced with a flexible laboratory networking system that allows faster, easier, and more productive collaboration.

AviationSimNet® is a real-time ATM simulation network using standard internet technology. It is a software environment that enables ATM simulation labs anywhere on the global Internet to integrate and work together simultaneously. Developed by The MITRE Corporation's Center for Advanced Aviation System Development (MITRE/CAASD) and implemented across the aviation community, this software system facilitates worldwide collaboration of real-time human-in-the-loop ATM simulation. This environment for simulating air traffic voice and data communications bridges MITRE/CAASD's ATM laboratories with other aviation laboratories across government, industry, and academia to enable distributed evaluation concepts.

**AviationSimNet® Participants:** Air Line Pilots Association, The Boeing corporation, Center for Applied ATM Research at Embry-Riddle Aeronautical University, Crown Consulting, Eurocontrol, Federal Aviation Administration, Lockheed Martin Transportation and Security Solutions, MITRE/CAASD, National Aeronautics and Space Administration (NASA) Ames Research Center, NASA Langley Research Center, Raytheon, and UPS.

**Cuts Costs, Time, and Risks.** Because it allows labs with complementary areas of expertise to collaborate, AviationSimNet can add a new dimension to any ATM study. Using standard internet-based technology and High Level Architecture (HLA) to leverage the combined lab capabilities of multiple organizations, users can:

- Enable distributed concept evaluation
- Work across the aviation community
- Specify standards for interoperability and flexibility
- Use the power of the public Internet

Participants all over the globe can use this environment to better leverage their mutual simulation capabilities and perform a wide range of critical cross-system ATM studies of new concepts, technologies, and procedures.

**Reusable, Reconfigurable and Secure.** AviationSimNet is a reusable, reconfigurable, collaborative, simulation environment. It is designed to efficiently and securely bridge aviation capabilities over the Internet. It does not require organizations to expose their internal networks and simulations. Instead, it uses a central HLA Run Time Infrastructure component housed on a publicly-accessible hub to connect and communicate data with other labs. The voice network supports an unlimited number of controllers, pilots, and frequencies and provides for pilots to dynamically change frequencies during all phases of flight.

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Communications, Navigation, and Surveillance/ Air Traffic Management (CNS/ATM) master plan is a plan for a needs-driven, economically justified, evolutionary system and modernization. The Plan must: (1) sustain systems necessary to maintain existing level of service; (2) introduce new operational procedures, technologies, and automation concepts necessary to meet user and operator needs; and (3) introduce appropriate program management structures for successful implementation of the Plan. Development of the Plan is shown in the Planning Process figure.

Why Have a CNS/ATM Master Plan?

International Civil Aviation Organization (ICAO) members have long understood that promoting air commerce is a key to their economic development. While currently stagnant due to events, air traffic is expected to resume significant growth over the remainder of the decade. The existing Air Traffic Control (ATC) infrastructure will need to undergo significant change to support this growth and to accommodate new technologies. The aviation environment is rapidly changing and ICAO members must adaptively respond to these changes in order to harmonize CNS/ATM systems across the national boundaries.

The long-term CNS/ATM Master Plan will provide for a systematic process to prioritize and balance investments. Several infrastructure changes already have been implemented in air commerce around the world. Space-based CNS technologies have made ATC systems more interdependent across national boundaries. ATC system enhancements, however, often require investments in avionics. Consequently, infrastructure enhancements are highly dependent on a common understanding between Civil Aviation Authorities and the aviation user community.

MITRE/CAASD Experience in Master Planning

The MITRE Corporation’s Center for Advanced Aviation System Development has focused not only on development of new CNS/ATM technologies necessary to enhance capacity and efficiency of global aviation systems, but also in the end-to-end, operational performance of the resulting integrated systems. We understand global trends and worldwide aviation needs. We have experience in budgeting, schedules, and risk management on both small and large scale airspace system projects.

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The United States air transportation system is a complex environment in which the actions of thousands of people, combined with acts of nature, ultimately determine the behavior of the system as a whole. Human decision making is involved in system operations at all levels, from the piloting of individual aircraft to the planning and management of air traffic flows regionally and nationally. In making decisions and taking the appropriate actions, decision makers draw on their own knowledge and expertise, as well as on information available to them on the current and predicted state of the air transportation system.

The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD), a federally funded research and development center sponsored by the Federal Aviation Administration (FAA), is exploring new ways to increase information sharing among decision makers. MITRE/CAASD is also investigating alternative concepts for interactive decision making and for sharing decision-making authority to take better advantage of available information, experience, and operational perspectives.

The overall goal of air traffic management (ATM) is to ensure safe, orderly, and expeditious air traffic flows. There are two groups of decisions makers: those who provide system services and those who use these services. The actions of these participants are based on the information available to them and on their individual goals. While all participants share the goal of a safe, efficient air transportation system, individual goals and definitions of what is efficient will vary and may sometimes conflict. For example, a controller’s primary goal is to safely separate air traffic. A traffic manager is concerned with keeping smooth traffic flows within safe capacities in the National Airspace System (NAS). An airline dispatcher is concerned with safety, airline operating efficiency, and profitability.

While the goal of ATM remains the same, the underlying philosophy has been changing. Recently, emphasis has been placed on collaborative ATM, which will integrate the role of flight planners, airline dispatchers, and aircrews into the decision-making process. The FAA and the users will work collaboratively to meet the overall goal of ensuring safe, orderly, and expeditious air traffic flows. In a collaborative ATM system:

- Service providers are focused on safety and equity.
- Airspace users are focused on their own operational and business objectives.

Current MITRE/CAASD research into collaborative ATM is focused on improving the decision-making process through better information sharing and decision support automation. Aspects of this new approach are already evident in today’s NAS operation. The FAA’s Enhanced Traffic Management System (ETMS), for example, provides real-time and predicted information about national air traffic flows and is currently used at FAA and international air traffic facilities. This information is also used by airline operational control centers. This tool provides a shared understanding of national traffic flows among a broad range of decision makers. In pursuing its collaborative ATM research, MITRE/CAASD is expanding the ETMS capabilities to provide for broader information sharing between service users and providers as well as additional decision support systems. These decision support systems will provide for more effective collaboration in the identification of flow problems and development of flow problem resolution strategies.

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Collaborative Routing Coordination Tools (CRCT)

Collaborative Routing Coordination Tools (CRCT) is an integrated collection of automation functions that traffic flow management can use to monitor traffic flows, develop strategies to alleviate congestion and avoid severe weather, and analyze the impact of proposed strategies. Using CRCT, a traffic manager can visualize the impact of a proposed strategy on sector loading or on individual aircraft. Eventually, the traffic manager will be able to share this information not only with traffic managers from other facilities, but also with airspace users. Thus, CRCT capabilities will help National Airspace System (NAS) stakeholders develop strategies for meeting their respective operating objectives when constraints in the NAS require traffic flow management action.

CRCT was developed by The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) as part of its Traffic Flow Management (TFM) Research and Development activities. CRCT currently exists on a research platform where operational concepts and automation functions are developed and evaluated by TFM personnel in their operational facilities and MITRE/CAASD’s lab. As a result of these evaluations, needs for capabilities are identified, desired capabilities are refined, and procedures for operational use are developed. When the Federal Aviation Administration (FAA) determines that a capability should be integrated into the TFM, MITRE/CAASD assists the FAA in transferring the technology to the implementation team and, where appropriate, the private sector.

Features

CRCT was developed to help traffic flow managers and airspace users address current shortfalls. Specifically, CRCT functions are designed to assist with the following:

- Visualizing future traffic flows based on filed flight plan information
- Identifying and analyzing potential TFM situations
- Identifying the flights that are expected to be directly impacted by the situation
- Defining candidate routes (either for traffic flows or specific flights) to alleviate the situation
- Analyzing the impact of a reroute strategy on sector loading for all the sectors across a region
- Enabling traffic flow managers from all facilities and airspace users to gain common situational awareness and information about strategy alternatives
- Facilitating the implementation of reroute strategies

Future Plans

MITRE/CAASD is currently developing new capabilities that will deliver additional operational benefits when combined with the initial CRCT capabilities; for example, development of capabilities to model Miles-in-Trail restrictions and to assess their impact, in concert with rerouting and ground delays. Research is also being conducted on computer-assisted resolution support to reduce time and workload. The FAA and MITRE/CAASD are preparing for field evaluations of these new features. MITRE/CAASD is also working with the FAA on transferring the technology associated with a desired CRCT capability; for example, flow constrained area application and trajectory modeling algorithms, to the FAA team responsible for integrating the CRCT capability into the traffic flow management system.

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With the continued growth of the Internet, expanded use of commercial off-the-shelf software, and government use of commercial networks, the threat environment to all networked infrastructures has been increasing steadily. These threats comprise both maliciously directed attacks against organizations and unintentional release and spread of viruses and worms within a network.

There is particular concern that critical infrastructures within the United States, which are dependent on network technology, have been targeted by foreign governments and terrorist organizations.

The MITRE Corporation’s Center for Advanced Aviation System Development (CAASD) is researching and developing means to protect the United States government’s critical networks from cyber attacks and to minimize damage when a cyber security incident occurs by providing direct support to the Federal Aviation Administration (FAA) and the Transportation Security Administration (TSA). As demonstrated by the 9/11 attacks, the disruption of commercial air traffic operations results in dramatic economic impacts well beyond the airline sector.

CAASD has reviewed the FAA’s National Airspace System (NAS) and developed a security architecture specifically designed for a safety critical environment. NAS has stringent performance requirements to support operations such as air traffic control and must, at the same time, maintain communications with many foreign agencies and aircraft operators. The NAS is a critical infrastructure that should be isolated from the public and from foreign governments, but cannot perform its mission without connecting to them. Further, the FAA must detect and respond to a cyber threat within seconds to maintain the safety tolerances demanded of air traffic control.

Any cyber security procedures for the NAS must be extensively evaluated and include safety and performance issues. The Communications and Information Systems Laboratory emulates all aspects of NAS Internet Protocol communications including routers, switches, air/ground data links, and future changes to the NAS. The laboratory is also organized on the same operational principles as the NAS, with Air Route Traffic Control Centers (ARTCCs) and the capability to support Terminal Radar Approach Control (TRACON) facilities. Security provisions are tested within the laboratory for applicability, performance, and failure modes, to determine suitability to the NAS (and similar safety dedicated infrastructures).

CAASD is improving FAA security operations by working directly with the Air Traffic Operations (ATO) organization and the Department of Transportation’s (DOT’s) Cyber Security Management Center (CSMC). Within the ATO organization, CAASD helped lead table-top exercises using real-life scenarios to identify response and communication gaps and process improvements. Teaming with both the ATO and CSMC, CAASD is helping improve cyber security monitoring, forensics, and reporting capabilities for the FAA.

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Why “End-Around Taxiways”. In response to increased air traffic, airports are constructing additional parallel runways to expedite the flow of landing and departing aircraft. In a typical parallel runway configuration, departing aircraft use the inboard runways and arriving aircraft use outboard runways. Arriving aircraft need to cross the inboard departure runways which can result in delays and risks of runway incursions. To reduce both the delays and risk of incursions, airports are proposing construction of taxiways that go around the end of the runway often referred to as “End-Around Taxiways” (EATs). These EATs are intended to allow aircraft to taxi around the end of the runway without interfering with operations on the runway (as would be required when crossing the runway). Because most cases involve EATs that would allow arrivals to taxi beyond the end of a departure runway, the initial focus was issues associated with allowing aircraft to depart over those taxiing aircraft.

Verifying the Safety of EATs Under Departures. A key concern that needed to be resolved before the Federal Aviation Administration (FAA) could approve the use of EATs beyond the departure end of the runway was verifying that the EATs could be operated safely. The Federal Aviation Administration (FAA) requested that The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) conduct a study to determine whether EAT operations met safety criteria as established in FAA’s Safety Management System (SMS). The study mined FAA and National Transportation Safety Board (NTSB) records of accidents and incidents over a 24-year period, identifying incidents that could pose a risk to an aircraft if it were on a taxiway beyond the end of the runway. The overall risk was estimated on a per departure basis, and showed that risk varies significantly according to the operator type of the departing aircraft and the distance to the end-around taxiway. MITRE/CAASD derived a risk formula that was used to demonstrate that the risk would remain within SMS guidelines if the FAA applied an appropriate risk management process that limited the number of implementations NAS-wide. Based on the results of this study, as well as an assessment of the human factors associated with EAT operations, FAA approved use of EATs under departures and issued design guidelines for EATs beyond the departure ends of runways.

Additional Cases. Several airport operators have also requested that FAA approve EATs that pass under arriving aircraft. MITRE/CAASD is performing a similar analysis to estimate the risk associated with these operations in support of such approval and to provide design guidance to airport operators.

Human Factors Issues with EATs. MITRE/CAASD provided human factors and experimental design expertise over the course of several simulations conducted at airline training centers and NASA Ames. During these evaluations, it became clear that pilots were having difficulty distinguishing between EAT aircraft and Runway Incursion (RI) aircraft. One study found 25% of the pilots could not correctly identify if an aircraft was crossing the departure runway, or was on the departure-end EAT, resulting in unnecessary rejected take-offs with EAT aircraft and failures to abort with runway incursion aircraft. Two mitigation strategies were examined in the final simulation. The first was a depression, where the EAT was depressed at varying depths below the runway threshold, and the second was a visual screen of varying heights placed between the end of the runway and the EAT. The depression and screen both provide an effective mitigation to help pilots distinguish between aircraft that are crossing the runway (causing an incursion) and those that are safely on the EAT. The arrival case is being evaluated to determine if there are additional human factors issues associated with arrivals over-flying aircraft on the EAT.

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As new operational procedures, equipment, and aircraft capabilities become available, the need for a more robust, efficient, and easier way of conducting complex safety analyses has been identified by the Federal Aviation Administration (FAA). Such a capability is needed to address the demand for safety analyses as the FAA transitions to new types of operations in all phases of flight.

The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) has developed a research platform for requirements elicitation called the Safety Assessment Toolset Prototype (SAT-P). The SAT-P builds upon the existing Collision Risk Model (CRM) and focuses on data integration, modeling complex obstacles, and providing a higher fidelity representation of air traffic and airport operational constraints needed to support safety assessment analyses. The prototype has helped the FAA define requirements for software tools to automate some of the labor intensive processes in setting up a safety analysis. It will also help the FAA prepare to incorporate new technologies and operations into their safety analyses and will support the transformation to a performance based National Airspace System (NAS).

Data Integration. The SAT-P provides the airport safety analyst with easy access to critical data and photo imagery, all geo-referenced for display and analysis within a geographic information system graphical user interface. The National Airspace System Repository database, integrated with the SAT-P, provides data on airports, runways, Instrument Landing System (ILS) approaches, Navigational Aids, and fixes. The Flight System Standards Information Service, a Web service linked to the SAT-P, provides data on obstacles in and around the airport environment. Obstacles can also be imported from the Digital Obstacle File database. Additionally, the SAT-P can display video maps, airport layout diagrams, ESRI Shapefiles, GeoTIFF files, satellite photo imagery of airports, and terrain data from the Digital Elevation Model and Digital Terrain Elevation Data.

Complex Obstacle Modeling. Often a safety analysis problem demands a more complex obstacle representation to account for the width and depth of the obstacle’s “footprint.” To address that need, the SAT-P demonstrates a capability to outline buildings and other elements requiring complex representation and enables the analyst to assign key properties, such as precise location and dimensions. The SAT-P then automatically generates a series of wall obstacles suitable for CRM analysis. A similar capability enables terrain features to be modeled as complex obstacles. Terrain contours are generated for areas of interest and represented as a series of point obstacles along the contours for CRM analysis.

Grid Obstacles. The SAT-P demonstrates a useful capability for analyzing candidate locations for proposed obstacles. The analyst can construct rectangular grids to represent multiple locations and height options for proposed obstacles. The SAT-P can then assess each cell location to determine its collision risk safety. This allows the analyst to run the CRM thousands of times to assess each cell together with other obstacles for various combinations of aircraft landing speeds and minimum obstacle clearance heights. Results are displayed graphically, making it easy for the analyst to view optimal locations for obstacle placement at an airport.

CRM Case Analysis for Multiple Runways/Airports. The CRM, originally designed to assess one runway/ILS at a time, has been integrated with the SAT-P to facilitate analysis of multiple runways at one or several airports as part of a single assessment case. The analyst can now construct one case to determine how changes in the CRM engine (e.g., visual segment risk calculation capability) or changes in an obstacle database may affect risk across several airports. The analyst is freed from the burden of setting up individual cases for each runway allowing them to promptly complete complex multi-airport analysis cases.

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A concept termed Flight Deck-Based Merging and Spacing (FDMS) is under development by a joint government/industry team led by the Federal Aviation Administration (FAA) Surveillance and Broadcast Services Program Office. With participation from the National Aeronautics and Space Administration (NASA), the Air Line Pilots Association (ALPA), Aviation Communication & Surveillance Systems (ACSS), UPS, Boeing, Honeywell, MITRE, and others, the team is conducting collaborative research and development to ensure the viability and safety of the FDMS concept. Based on past research and development done in the U.S. and Europe, FDMS gives flight crews the ability to use speed management derived from on-board equipment to achieve and maintain in-trail spacing. This operation is intended to reduce the need for air traffic control (ATC) interventions and provide for the delivery of accurate, low-variance spacing for merging and arriving aircraft.

The FDMS procedure utilizes the FAA's cornerstone future surveillance system known as Automatic Dependent Surveillance – Broadcast (ADS-B) for the aircraft-to-aircraft broadcast of precise position and velocity information. This information allows pilots to track the movement of their own and other aircraft on a cockpit display. FDMS permits flight crews aboard properly equipped aircraft to assist the controller in maintaining spacing within aircraft pairs. During Continuous Descent Arrival (CDA) operations, FDMS can help maintain capacity by optimizing the overall spacing among a stream of aircraft.

MITRE recently conducted a series of pilot and controller human-in-the-loop evaluations in simulated en route and terminal flight environments so that the FDMS procedure could be iteratively tested and refined. Our simulations affirmed that FDMS can minimize the need for controller interventions with traffic, reducing time and distance flown as well as the voice communications load. This research, coupled with demonstrations to key FAA officials, helped mature the concept and support its introduction to the field. ACSS has recently gained FAA approval to install FDMS equipment on Boeing 757s, and UPS has applied for FAA’s permission to conduct the FDMS operation.

The fielding of spacing concepts such as FDMS, enabled through advances in technology such as ADS-B, is a necessary initial step to realization of the FAA’s Next Generation Air Transportation System (NextGen) and Europe’s Single European Sky Air Traffic Management (ATM) Research (SESAR). These visions are intended to increase the safety, security, and capacity of future air transportation operations to address the expected public demand.

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Global Positioning System for Civil Air Navigation

In December 1993, the Department of Defense declared initial operational capability for a new high-technology radio navigation system, the Global Positioning System (GPS). Based on studies done by The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) and others, the Federal Aviation Administration (FAA) and the aviation community recognize that while GPS provides a beneficial operational capability to many users, aviators operating under instrument flight rules require augmentation.

MITRE/CAASD has helped the FAA identify various aspects of GPS performance that must be improved to support high-availability GPS flight operations, including precision approach and airport surface operations. These components include signal integrity, signal accuracy, and system availability.

To achieve these improvements and to expedite GPS use for vertically-guided instrument approaches, MITRE/CAASD helped define the Wide Area Augmentation System (WAAS), a capability that adds differential corrections and ranging information to information relayed by geostationary satellites. As part of this effort, MITRE/CAASD also developed and tested algorithms to mitigate the effects of signal delays in the ionosphere and to ensure the integrity of broadcast ionospheric delay corrections. MITRE/CAASD also helped to establish performance requirements for WAAS and had an important role in the transfer of technology to the prime contractor. To ensure that the WAAS design achieved the necessary degree of integrity for vertically-guided approaches, the FAA established a WAAS Integrity Performance Panel (WIPP)—consisting of MITRE/CAASD, industry, and academia—that worked with the prime contractor throughout the implementation of WAAS. WAAS achieved Initial Operational Capability in July 2003.

To help the FAA determine the number and location of reference stations to meet specified requirements, MITRE/CAASD developed a Satellite-Based Augmentation System (SBAS) Worldwide Availability Tool (SWAT). The SWAT predicts the performance of an integrated network of satellites, ground stations, and communication links. MITRE/CAASD is currently working with the FAA to define WAAS enhancements for the Full Operational Capability system.

MITRE/CAASD is also working with the FAA to develop the Local Area Augmentation System (LAAS). LAAS provides corrections via a Very High Frequency data broadcast to aircraft within line-of-sight distances. It is being developed to provide precision approach capability for all the runways at an airport equipped with LAAS. MITRE/CAASD’s role in specification development and validation includes analyses of signal integrity and availability. In addition to LAAS specification activities, MITRE/CAASD has also provided technical expertise to FAA/industry partnerships, FAA’s Key Technical Advisors on LAAS, and the LAAS Integrity Panel. MITRE/CAASD is working with the FAA to ensure the integrity and safety of a future LAAS system that will support landings to Category III standards.

MITRE/CAASD is also helping to define requirements for a modernized GPS system in which multiple frequencies will be available to civil users. Finally, MITRE/CAASD is working across the international community to assure signal compatibility between future GPS and future international satellite navigation capabilities.

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The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD), supports the Federal Aviation Administration’s (FAA) Federally Funded Research and Development Center, in meeting its Safety Management System (SMS) guidelines. MITRE/CAASD is involved in evaluating safety risks associated with proposed changes to National Airspace System (NAS) automation, procedures, airspace, and facilities and conducts Operational Safety Assessments (OSAs) to define the safety requirements associated with those proposed changes. Bow-tie models, are used to identify and assess the safety risks of all potential operational hazards. Hazards are identified based on a detailed description of the change and the environmental conditions under which the application will be operating.

To mitigate the effects of the hazard, they are expressed for both the detected and undetected case at the boundary of the change. Hazards are identified based on modeling and the identification of abnormal events. Operational Hazard Assessments (OHAs) are conducted to assess the operational effects specifically attributable to the proposed NAS change and to set the safety objective for each hazard. After accounting for external mitigation means, these become the safety requirements. The Allocation of Safety Objectives and Requirements (ASOR) process is conducted to ensure that the safety requirements are addressed within the proposed NAS change. The ASOR objective is to identify the basic causes leading to the operational hazard, along with the associated fault tree and the allocation of the lower level safety objective(s). Based on these, the corresponding safety requirements per domain are defined to meet the overall operational hazard safety objective, taking into account the identified internal mitigation means.

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Implementing TFM Reroutes:
An Integrated Approach

In order to promote improved information exchange, situational awareness, decision making, and strategy implementation between traffic flow management (TFM), air traffic control (ATC), and the airspace users, The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) has developed an operational concept for how TFM-derived reroutes can be integrated between TFM, ATC, flight planning, and flight deck capabilities.

Background

Although the Federal Aviation Administration (FAA) and the airspace users collaborate on the reroute strategy, it is nevertheless cumbersome to implement. The efforts needed to identify the flights that need to be rerouted and to manually implement the new route as a refiled flight plan or a flight plan amendment can take an inordinate amount of time. Further, TFM needs to have the best and latest information on all intended routes of flight in order to maximize the effectiveness of TFM decisions. This is precluded if there is uncertainty in how reroutes will be addressed. From the airspace user’s perspective, knowledge of TFM initiatives and ATC-specific restrictions facilitates the flight planning process. The implementation of rerouting strategies can be facilitated through integration of planned and existing automation systems. New capabilities in the Enhanced Traffic Management System allow for the identification of the flights affected by a rerouting advisory. This enables electronic communication of the reroutes and provides a means by which the National Airspace System can be made more efficient and predictable.

The Components

In practical terms, integration of TFM rerouting initiatives is achieved as follows: The coordination and implementation of rerouting initiatives relies on the core concept of determining exactly which flights are affected by the initiative. Early coordination of this "reroute list" enables users to plan around the constraints causing the reroute (congestion, severe weather, or other ATM restrictions). For flights already airborne, TFM can use the rerouting list in an interface with ATM automation to facilitate the transmittal of the TFM strategy.

Flight Planning

Traffic flow managers will notify flight planners that planned flights are potentially affected by TFM initiatives, allowing the planners to incorporate the initiative into their routes or to plan around the constraint. In addition, knowledge of ATC-specific restrictions, such as ATC-preferred routes, improves awareness of how the flight will actually be flown.

ATC

An interface with TFM automation enables the incorporation of rerouting strategies into ATM automation, thereby eliminating the effort of determining which flights are affected. The desired reroute can be automatically integrated into ATM capabilities to assess the impact of the reroute on the sector plan and to facilitate the entry of the necessary flight plan amendments.

Flight Deck

Once the reroute has been assessed by ATC, it can be sent via data link to the cockpit, eliminating the need for lengthy and potentially misunderstood verbal clearances, thereby creating opportunities to integrate the data link clearance with onboard flight management systems.

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Integrated ATM Laboratory

To enable improvements to today's air traffic management systems, and to envision the needs and possibilities for tomorrow, analysts need an experimental setting in which concepts can be matured and vetted with key stakeholder groups. This environment must be robust enough to handle a range of exploratory concepts, and yet realistic enough to provide a quality user experience. It is with these needs in mind that The MITRE Corporation's Center for Advanced Aviation System Development (MITRE/CAASD) developed its Integrated Air Traffic Management (ATM) Laboratory. The Integrated ATM Laboratory is an extensible, scalable, real-time distributed simulation environment based on an open, layered architecture. It brings together a broad set of integrated air traffic management capabilities for human-in-the-loop simulation and visualization.

Enabling Faster, Better-Informed Decision Making.

In MITRE/CAASD's Integrated ATM Laboratory, pilots, controllers, airlines and other key stakeholders can work with and view simulated concepts individually, side-by-side or in an integrated, end-to-end fashion. The lab provides an environment for all parties to share the experience of a proposed concept change, discuss their concerns on workload, communication, safety, roles and responsibilities, and other topics. Because this allows them to come to an agreement more quickly through visualization, iterative changes and evaluations, it can lead to faster implementation of beneficial enhancements.

Fully Integrated Technology for Far Reaching Results.

The Integrated ATM Laboratory offers a broad range of integrated capabilities:

- **Cockpit Simulation**: A medium-fidelity re-configurable fixed-base cockpit simulator coupled to an out-the-window visualization system with a 124 degree field of view.
- **En Route Simulation**: An air traffic control simulation capability that provides a sector suite configuration and interactive sim-pilots. The sector suite configuration includes emulated radar displays, strategic planning and decision-support tools including a conflict detection, trial planning and flight information management through the User Request Evaluation Tool (URET). The en route simulation capability can simulate any number of sectors across the country with current or future airspace adaptation.
- **Terminal Simulation**: A TRACON simulation capable of simulating a variety of current and future operating environments including the ARTS/3E or Common ARTS radar displays. This simulation capability also includes sim-pilot capabilities.
- **Tower Simulation**: A tower simulation capability that includes a BRIT display and provides surface movement of aircraft. This capability can also be used to look at future airport configurations.
- **Traffic Flow Management**: The Collaborative Routing Coordination Tool is a high-fidelity prototype of an integrated collection of traffic management automation functions.
- **Portable Aviation Visualization Environment**: A 3-D Visualization environment that is used in conjunction with the cockpit simulation, tower simulation or separately to provide visual representation of physical and abstract concepts.

Integrated Simulation Testing Leads to ATM Advances.

Working in the Integrated ATM Laboratory together with the Federal Aviation Administration, National Air Traffic Controller’s Association, Airline Pilots Association, civil aviation authorities of various countries, and other organizations, MITRE/CAASD has helped improve ATM systems in a number of key areas, including:

- Runway safety initiatives
- Airspace redesign
- Traffic Flow Management
- Enroute Decision Support Systems
- Applications of the Automatic Dependent Surveillance-Broadcast/Cockpit Display of Traffic Information (ADS-B/CDTI) to procedural applications
- Airport/Runway Siting

Towards Global ATM Integration.

One of the newest capabilities added to CAASD's Integrated ATM Laboratory is a real-time ATM simulation network using standard internet technology, called AviationSimNet. AviationSimNet enables ATM simulation labs anywhere on the global internet to integrate and work together simultaneously. Developed by MITRE/CAASD and implemented across the aviation community, this capability facilitates worldwide collaboration of real-time human-in-the-loop ATM simulation.

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Integrating Common Flight Data Processing in the National Airspace System

To address the future needs of the Federal Aviation Administration's (FAA) National Airspace System (NAS) infrastructure, The MITRE Corporation's Center for Advanced Aviation System Development (MITRE/CAASD) has employed a standardized architecture analysis technique to define a potential evolution of NAS Flight Data Processing (FDP) capabilities. Taking advantage of its broad aviation expertise, MITRE/CAASD analyzed and documented the current FDP architecture encompassing major FDP systems across the domains of the NAS, assessed the impact of future concepts on this architecture, and is taking steps to define a more cost-effective and efficient integrated Air Traffic Management system for handling future air traffic demands.

Integrated NAS Infrastructure Goal. The figure below depicts the goal of data and function commonality across domains, including improved information exchange. In addition, a wide-range of new capacity enhancing capabilities are being planned that will rely on uniformly consistent and accurate flight information, at a level that does not exist in today's NAS. It is vital that FDP capabilities evolve in a way that enables the FAA to continue delivering services effectively in the face of increasing and changing demand. This evolution must be coordinated with flight data initiatives within the NAS domains and around the world to ensure interoperability, both domestically and globally.

Assessing Today’s Architecture for Tomorrow’s Solutions. MITRE/CAASD captured current FDP operations in a series of system threads that depict information and activity flows between automation systems and system users in all phases of flight, from pre-flight through post-analysis. Additional threads were developed to reflect the impact on operations resulting from the FAA's vision for the future. The future threads can be used in two principal ways. First, analyzing how these functions serve the domains will help determine which FDP functions are common across multiple domains. Second, the threads can serve to validate future architectural approaches for implementing specific improvements in NAS operations.

Applying an Architecture Framework to Evaluate Commonality. As shown in the figure below, the thread definition was augmented with a functional analysis of common FDP capabilities, leading to a definition of a future integrated NAS architecture. Using an architecture framework approach, that has been adopted by government agencies and commercial industries as a methodology to develop large scale systems, MITRE/CAASD developed a set of architecture framework products:

- Operational Activity Models—used as the standard notation to model the hierarchy of actions and activities of NAS service providers in all phases of flight.
- System Functionality Descriptions—functional decomposition of current system functions, system context diagrams, and functional flow diagrams for internal and external data flows.
- Operational Activity-to-System Function Correlation Matrices—describe how FDP functions in each of the current systems relate to one another in supporting the operational mission within and across domains.

Defining Common FDP Capabilities for the Future. By using these architectural products to focus the analysis, common FDP capabilities were identified across systems. A comparative analysis highlighted the potential areas of future commonality. Finally, a set of characteristics was identified for future common FDP capabilities which could serve all of the applications embodied in the current systems while supporting the operational mission. MITRE/CAASD is continuing this analysis with an examination of systems planned for the future, incorporating their capabilities in the FDP architecture definition, and evaluating potential evolutionary steps.

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Integration of Advanced Simulation Technologies into Controller Training

The Federal Aviation Administration (FAA) faces the challenge of training approximately 12,000 new enroute and terminal air traffic controllers over the next decade to fill the void left by retiring controllers. In addition, evolution of the Next Generation Air Transportation System (NextGen) will require training innovations to effectively transition to new Air Traffic Control (ATC) capabilities and operational procedures. Currently, training and certifying a controller is a lengthy and subjective process that requires significant human resources. The current system cannot effectively meet the near-term or the mid-to-far-term training needs.

In 2004, The MITRE Corporation’s Center for Advanced Aviation System Development (CAASD) conducted research to determine advanced techniques for improving controller training. CAASD examined the training innovations being implemented in military and European ATC systems. The results indicated that advanced simulation and training technology, as part of intelligent training system (ITS) design, are critical to improving the effectiveness, efficiency, and flexibility of controller training. An ITS will enable self-paced and accelerated training and increased standardization, while reducing training costs. This is a key enabler to support the evolution of the National Airspace System (NAS) toward NextGen.

CAASD developed a comprehensive plan that recommended advanced training technology and process enhancements, many of which were included in the FAA’s March 2007 Workforce Management Plan. CAASD leveraged advancements in aviation system design, new prototype technologies, and field evaluation data to develop a stand-alone enroute simulation prototype, known as the MITRE enroute Trainer. With its high-fidelity, scenario-based instruction, the enroute Trainer provides students with a realistic environment, simulating the effect of winds, aircraft climb/descent rates, and aberrant conditions. The system’s speech recognition and synthesis capabilities simulate pilot/controller interaction, enabling self-paced training, reduced reliance on human resources, and increased standardization. The enroute Trainer enables the instructor to pause and play back any trainee scenario and it presents an assessment of a student’s performance upon instructor request.

The enroute Trainer is currently being evaluated at the FAA’s Indianapolis Air Route Traffic Control Center to provide Stage IV Radar Simulation training. The primary objective of this evaluation is to validate the enhanced simulation capabilities and curriculum elements that should be integrated across the NAS for controller training. It is expected that these changes will shorten training time, reduce the cost to certify a controller, improve the quality and consistency of training, and provide more flexibility to make frequent automation and procedural advancements as the FAA moves toward NextGen.

Results from the field trials indicate that the enroute Trainer provides improved training context and streamlined processes that better prepare trainees to control live traffic. Specific qualitative and quantitative benefits are being assessed as groups of students complete their training. The first group of students to use enroute Trainer completed their on-the-job-training in 25% less time than expected and achieved Certified Professional Controller status seven months ahead of schedule. Based on these positive results, CAASD is working with the FAA to transfer this technology to industry for broad application across the FAA's controller training program.

Many of the capabilities of the enroute Trainer can be leveraged for the FAA's terminal environment. CAASD is working in partnership with the FAA's Miami Terminal Radar Approach Control training staff to develop an initial terminal Trainer prototype that demonstrates the use of interactive training techniques, performance measurement, and real-time feedback to effectively deliver airspace and procedure training via enhanced simulation.

As the FAA’s Federally Funded Research and Development Center, CAASD will continue to explore new training processes and technologies for enroute and terminal ATC training NextGen to help the FAA to keep up with the ATC hiring curve and the demand for new and advanced ATC services.

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All nations are concerned for the safety of their traveling citizens. This concern has manifested itself in increased oversight of civil aviation authorities (CAAs) by various foreign and international agencies. International programs, such as the International Civil Aviation Organization’s (ICAO) Universal Safety Oversight Audit Program, the European Union Safety Assessment Foreign Aircraft Program, and the U.S. Federal Aviation Administration (FAA) International Aviation Safety Assistance (IASA) Program, are designed to evaluate the adequacy of CAA’s safety oversight of its operators. Audits and assessments carried out to date indicate many states are having difficulty fulfilling their safety oversight obligations, which can have far-reaching economic and political consequences for the country, the CAA, and the airlines. Starting in 2004, ICAO will expand its safety oversight program to include Air Traffic Control (Annex 1, 11), Aerodromes (Annex 14), and Accident Investigation (Annex 13).

Aviation Safety Assistance

The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) has provided support and consultation to international civil aviation authorities, airport authorities, and other aviation organizations in the areas of safety oversight, safety management systems, systems engineering, aviation operations, and systems integration.

As a federally funded research and development center sponsored by the FAA, MITRE/CAASD is uniquely qualified to help clients integrate operational needs with technical capabilities. To this end, we are committed to bringing together a team of professionals to provide state-of-the-art solutions to real-world problems. MITRE/CAASD is uniquely qualified to support a variety of aviation safety projects.

In recent safety projects, we supported the Egyptian Civil Aviation Authority (ECAA), the Hellenic Civil Aviation Authority of Greece, the Republic of China’s Air Traffic Service’s department, the Republic of Korea CAA’s Aeronautical Telecommunications department, and the operator of all Argentina’s airports in modernizing their safety oversight programs and Safety Management Systems (SMS). These projects included assessments of the CAAs’ compliance with ICAO Standards and Recommended Practices (SARPs); including Annexes 1, 6, 8, 10, 11, 14, 15, and 17 for aviation safety oversight and SMS program development. Following the assessments, we developed action plans to address corrective actions; assisted in preparing new aviation laws and regulations, safety inspector handbooks, and policy and procedures manuals; provided surveillance scheduling; designed a regulatory tracking system; and provided inspector training. MITRE/CAASD was recognized by the ECAA Chairman and the Director of the Republic of China’s Air Traffic Services Division for our significant role in preparing their organizations for FAA IASA and the ICAO Safety Oversight Audits for Annexes 1, 6, 8, 11, and 14. At the conclusion of their assessments, ICAO and the FAA reported that Egypt was in full compliance with International Standards for safety oversight of its airlines. MITRE/CAASD also provided technical assistance to EgyptAir in developing safety and certification programs, maintenance quality control programs, an operations control center, and performance baseline programs. MITRE/CAASD offers its clients extensive experience in Safety Management Systems development for the related ICAO SARPs. MITRE/CAASD has developed and implemented three disciplines of aviation safety systems Flight Standards, Air Traffic Services and Airports. Safety management system specialists are subject matter experts with many years of relevant discipline experience. Assessment results are proprietary and action plans mitigate deficiencies. Specialists are ISO 9001:2000 certified as Lead Internal Quality Auditors and members of the American Society of Quality.

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The MITRE Aviation Institute (MAI) provides professional development opportunities to the global aviation community. Synthesizing a broad spectrum of aviation expertise, the MAI draws on almost 50 years of worldwide corporate knowledge in aviation research and engineering to deliver a unique learning experience. The MAI helps to cultivate an industry-wide collaborative culture via interactive hands-on courses in key areas. MAI courses are designed to help the global aviation community bring the best it has to bear on future challenges.

Applying Proven Disciplines. The MAI offers instruction in several core disciplines:
- Communications, Navigation, and Surveillance/Air Traffic Management (CNS/ATM)
- Airspace Planning and Analysis
- Aviation Safety Management Systems (SMS)
- Area Navigation/Required Navigation Performance (RNAV/RNP)
- Aviation Safety and Security
- Spectrum Management
- Unmanned Aircraft Systems

Instruction formats include:
- Executive Briefings
- Short Courses
- Seminars & Conferences
- Workshops

Addressing Critical Global Issues. Air traffic demand is at an all-time high and increases every year. Research centers, universities, airlines, civil aviation authorities, and aircraft manufacturers are working to improve the outlook for meeting this demand. The MAI combines technology, operations knowledge, systems engineering, and practical strategies to address the challenges of Air Traffic Management in the 21st Century.

Building Partnerships that make a Difference. To complement MITRE’s systems engineering and aviation expertise, the MAI is working with organizations that foster aviation knowledge sharing:
- Federal Aviation Administration Academy
- Air Traffic Control Association
- American Association of Airport Executives
- Embry-Riddle Aeronautical University

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The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) has developed an array of innovative diagnostic tools to help assess the performance of the National Airspace System (NAS) such as the Airport Specific Analysis Page (ASAP) and the All NAS Display.

ASAP is used to give an analyst a quick glance at the Airport Acceptance Rate (Arr_Rate), Official Airline Guide (OAG) scheduled arrivals and departures (OAG_Arr, OAG_Dep), Aviation System Performance Metrics (ASPM) actual arrivals and departures (Arr_Ct, Dep_Ct), Convective Weather (CW), Ground Delay Programs (GDP), Ground Stops (GS), airborne holding and diversions, all for a single day at a single airport. In addition, FAA Operations Network delay statistics are included in the area shaded in green. This example is for Atlanta (ATL) on July 19, 2007.

The All-NAS Display is an interactive tool to display overlaid information about Enhanced Traffic Management System (ETMS) flight tracks, convective weather, Traffic Flow Management Initiatives, as well as CAASD-derived metrics such as airborne holding and vectoring. It also allows the user to extensively customize the visualization.

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Aviation is a critical part of the U.S. economy. Increases in air traffic volume and complexity, combined with projected budget constraints over the coming years, will create challenges for our nation’s Air Traffic Management (ATM) system. The safety, capacity, and productivity of the National Airspace System (NAS) can be significantly improved through the Operational Evolution Partnership (OEP) that comprises an integration of enhanced ground and air automation technologies and procedures, enabling operational demands on the NAS to be met in a safe and more efficient manner.

In partnership with the Federal Aviation Administration (FAA), The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD), has developed an operational concept as a subset of the OEP evolution to NextGen, known as Performance-Based ATM. This concept introduces fundamental shifts in the use of automation capabilities across the NAS that increases operational productivity while still maintaining a human-centered operation. This shift is based on a cross-domain set of capabilities, procedures, and concepts that will revolutionize the way the FAA operates its air traffic system. The Performance-Based ATM validation activities focus on a set of operational changes that can be achieved in an evolutionary manner through OEP.

Under the Performance-Based ATM concept, many routine air traffic control tasks will be automated. Terminal operations will leverage a network of highly precise RNAV/RNP routes. These routes would be designed to increase flexibility, efficiency, and capacity. The flight deck automation would enable aircraft to fly these routes and altitude profiles precisely while exchanging flight status and intent information with the ground system. In En Route operations, responsibility for problem prediction would migrate from controllers to ground automation, and controllers would solve problems using automated resolution assistance. The integration of advanced automation with air/ground data communications would assist the controllers in accommodating pilot requests and providing more efficient maneuvers when resolving predicted conflicts.

The Performance-Based ATM concept provides for better management of uncertainty with capabilities that support enhanced decision-making and efficient execution of flight-specific initiatives. The reduction in execution time, along with improved tools for defining and monitoring the initiatives, would allow for better traffic flow planning and provide the opportunity to implement initiatives incrementally and only when necessary. In this highly-predictable operational environment, user preferences would be better accommodated through collaborative ATM activities. The Performance-Based ATM portfolio of capabilities can provide vastly improved air traffic services that promote increased safety, capacity, efficiency and operational productivity.

The FAA and CAASD are validating the Performance-Based ATM concept through human-in-the-loop laboratory experiments. FAA En Route and Terminal Front Line Managers from all around the country have actively participated in assessing both the quantitative benefits as well as the operational feasibility of this concept. The FAA Vice Presidents from across the Air Traffic Organization lines of business (including Terminal Services, En Route and Oceanic Services, System Operations, and Operations Planning) and the Joint Planning and Development Office have been the primary sponsors for this research as they plan for the future.

The Performance-Based ATM research and validation activities will continue to inform OEP activities for transforming air traffic operations toward NextGen and changing the controllers’ roles and responsibilities in order to safely and efficiently meet the future demand on the NAS.

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The Portable Aviation Visualization Environment (PAVE) is a 3D rendering system used to visualize multiple data sets in real-time. The basic environment is a collection of digital terrain, aerial photography, and AutoCAD surveys, that are combined to create a realistic 3D representation of an airport and its surroundings. This model is then used as a backdrop to present concepts such as:

- Airport, Runway, and Tower Sighting
- Airport Surface Markings, Signage, and Lighting
- Noise Contours
- Procedure Paths and Waypoints
- Geospatial and Temporal Sensor Data
- Surveillance Coverage Areas, and Threat Analysis

This visualization capability is part of an overall service that The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) provides to its customers to aid in the presentation and demonstration of new concepts. It is currently used as a portable capability to present airport surface markings, lighting designs, and Required Navigation Performance enabled approaches in the United States, just to name a few. It has also been successfully used with noise analysis and airport siting. The environment provides the ability to view procedure paths, data points, and/or airport layouts from multiple perspectives. These perspectives range from an aircraft cockpit, tower controller, and ground personnel to virtual views such as high-altitude or “tethered” viewpoints. This flexibility gives analysts, and ultimately our sponsors, the capability to make more informed decisions by examining problems from all sides. The system was developed by MITRE/CAASD specifically for the aviation industry, enabling project specific customization. In addition, the visual databases are built using high resolution geo-registered data sets to create a state-of-the-art software solution. This software package can be installed and run on a standard desktop computer, with the addition of a high-end 3D rendering card.

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In response to FAA’s Flight Plan Objective 4 and NTSB safety recommendations, The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD), in cooperation with the Federal Aviation Administration (FAA) and Massachusetts Institute of Technology (MIT) Lincoln Laboratories, is developing operations concepts and a ground movement safety system designed to provide direct warning to pilots on the flight deck that a runway incursion threat exists. The system consists of six components, passive, low technology elements, and active, surveillance-driven elements, which in combination provide pilots with enhanced situation awareness regarding runway proximity and both actual and predicted runway occupancy.

Surface Painted Markings and Modified Centerline Lights: Low Tech, High Safety, Enhanced Surface Painted Marking System. Enhanced surface painted markings provide runway awareness information to pilots by changing the appearance of the taxiway centerline within 150’ of the runway hold short line.

Modified Centerline Lights. The modified centerline lights provide runway awareness beyond the hold short position, by using alternating amber and green centerline lights when beyond the runway hold line.

Runway Status Lights: Active Warnings Directly to Pilots Runway

Entrance Lights (RELs). RELs protect against incursions taxiway – runway intersections. They illuminate red when the runway is occupied or predicted to be occupied.

Takeoff Hold Lights (THL). THLs illuminate when it would be unsafe to initiate a takeoff due to an occupied runway or predicted conflict at a runway intersection.

Runway Intersection Lights (RILs). RILs function similarly to RELs to provide runway status information to aircraft approaching a runway intersection during landing rollout, departures, or using runways for portions of a taxi route.

Final Approach and Runway Occupancy Signal (FAROS). FAROS provides alerts to pilots on approach that a runway may still be occupied with sufficient time to safely perform a go-around. The system may use lights or a combination of lights and aural messages to the cockpit.

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The current terminal area airspace design philosophy centers on defining point-to-point area navigation (RNAV) routes. For arriving aircraft, these routes extend the Standard Arrival Routes (STARS) farther into the terminal area with the routes terminating on the downwind or at an initial approach fix—a benefit which takes advantage of the predictability and repeat ability of RNAV equipped aircraft flying the routes, resulting in a reduction of needed controller vectoring of aircraft aidless required air-to-ground communications. This results in increased safety and efficiency in the terminal area.

These benefits will accrue only if aircraft stay on their RNAV routes and the control procedures are such that communications are minimized.

Several high demand airports have routes that merge in the terminal area before joining the final approach. If this doesn't occur, almost all high demand airports have routes that merge just prior to the final approach unless the airport has a unique geometry where each entry point to the terminal area can be assigned its own runway.

The Roadmap for Performance Based Navigation has as an implementation strategy “in terminal areas with merging RNAV arrival streams, implements flow management through metering and tactical controller tools that maximize the efficiency and throughput for RNAV arrival operations.” The MITRE Corporation's Center for Advanced Aviation System Development (MITRE/CAASD) has researched different tools to address this need.

The Relative Position Indicator (RPI) is a tool that can assist both the controller and the traffic management coordinator (TMC) in managing the flow of traffic through a terminal area merge point.

RPI places a symbol or marker on the controller’s or TMC’s display to indicate where the aircraft on the merging route is currently positioned. The tool takes into account all of the non-linear segments and turn arcs of both routes prior to the merge point.

With the use of RPI, the TMC can determine early in the coordination process whether the two flows of traffic can be merged without undue control actions. Similarly, controllers can also determine what early control actions can be taken, such as speed control that will keep the aircraft from being vectored off its route.

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Runway Safety Simulation

Through its Integrated Air Traffic Management (ATM) laboratory capability, MITRE’s Center for Advanced Aviation System Development (MITRE/CAASD) has combined the newest information technology with systems engineering, modeling, and simulation to produce results that are operationally viable. MITRE/CAASD is dedicated to improving aviation system safety, security, and performance and has created a cockpit simulation that incorporates several runway safety technologies that have been fielded or are currently being researched. This simulation provides users the ability to interact with these systems and includes many runway safety technologies (including the Ground Marker Beacon System).

**Final Approach Runway Occupancy Signal (FAROS).** When pilots are on final approach for landing, in certain conditions such as haze or nighttime, it is difficult to distinguish an aircraft that is already on the runway and pointing directly away from an arriving aircraft. The Flashing Precision Approach Path Indicator (FPAPI) system provides a visual indication of runway occupancy status directly to landing pilots. When the FPAPI lights begin flashing, the landing pilot is immediately alerted to the possibility of an occupied runway.

**Enhanced Surface Markings.** These are intended to improve awareness of the runway environment and conspicuity of runway holding position markings. The Enhanced Surface Markings include extending the Runway Holding Position Markings beyond the taxiway edge lines; changing the dashes on the Holding Position Markings from yellow to white; painting a Surface Painted Holding Position Sign on each side of the taxiway centerline; and painting Dashed Yellow Lines on both sides of the taxiway centerline.

**Surface Moving Map.** The Airport Surface Situational Awareness (ASSA) application is intended to reduce the likelihood of pilot disorientation on the airport surface by superimposing the pilot’s current position upon a map of the airport surface. The ASSA application is flight deck-based and includes the depiction of owndship position, traffic position, and a surface moving map (including runways, taxiways, holding areas, ramps, hangars, and prominent airport structures, etc.) on a cockpit display. The surface moving map display can give important information about nearby traffic, such as ground speed and current heading, to help the pilot anticipate turns or deceleration of the traffic.

**Runway Guard Lights (RGLs).** RGLs are yellow flashing lights that designate hold points prior to active runways. They provide a distinctive warning to anyone approaching the runway holding position that they are about to enter an active runway. Below 1200 Runway Visual Range (RVR) – all taxiways, whether part of low visibility route or not will have RGLs.

**Taxiway Lead-on Lighting.** The FAA is investigating a modified lighting configuration for taxiway centerline runway lead-on lights. Under the current standard, the color pattern of taxiway centerline runway lead-on lights is all green, while the pattern for runway lead-off lights is alternating green and yellow. Under the proposed change, the color pattern for both lead-on and lead-off lights would be alternating green and yellow.

**Runway Status Lights (RWSLs).** RWSLs are a lighting system designed to reduce the risk of runway incursions by warning the pilot when the potential for an incursion exists. RWSLs provide this warning in the form of red lights at the runway holding position marking (Runway Entrance Lights (RELs)) and on the runway (Takeoff Hold Lights (THLs)). When the surveillance network driven RWSL system, detects an aircraft in the process of taking off, and/or an aircraft crossing the runway, red lights RELs or on the THLs, illuminate.

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Managing the scarce and valuable frequency resources of a nationwide air/ground (A/G) radio system is an immensely complex task. High-altitude airborne radios are mutually visible at very long ranges, increasing their exposure to co-channel interference and hindering frequency reuse. Ground-based A/G radios often share crowded sites where the threat of co-site interference greatly reduces the supply of usable frequencies.

As air traffic grows, the size and complexity of the A/G radio system grows with it, and so does the magnitude of the spectrum manager's task. Planned changes in the architecture of the worldwide very high frequency (VHF) A/G radio system will intensify these difficulties during the prolonged period of transition to the new architecture. Detailed, time-sequenced frequency plans must be developed to ensure a gradual, non-disruptive transition in which interference-prevention rules will be followed at every step. Automated support is essential for creating those transitional frequency plans.

For several years, The MITRE Corporation's Center for Advanced Aviation System Development (MITRE/CAASD) has supported the Federal Aviation Administration (FAA) in planning the future evolution of the nationwide A/G radio system for air traffic services. A key component of that support has been CAASD's development and use of spectrumProspector, an automated tool tailored to the needs of A/G radio spectrum management.

spectrumProspector models the desired and undesired electromagnetic interactions of large populations of A/G radios and potential sources of interference to those radios. The tool is highly flexible and has many applications, including day-to-day frequency planning to meet new circuit requirements, spectrum planning for facility relocations or airspace redesign, predicting the effect of proposed radio design changes on spectrum-limited system capacity, and long-range spectrum planning for an architectural transition.

The Simulation Database contains user-supplied environmental data, lists of available frequencies, and frequency-assignment rules.

The Assignment Engine. spectrumProspector's assignment engine automatically generates a frequency plan for the postulated environment in accordance with the rules specified by the user. It has several user-selectable assignment strategies. The "gapfilling" strategy is the simplest and keeps all preexisting circuits on their old frequencies while the engine seeks violation-free assignments for one or more new circuits. In cases where spectral congestion is severe, the more powerful "neighbor-repacking" strategy generates incremental frequency plans in which preexisting assignments are successively changed to create spectral room for new circuits. spectrumProspector's "architecture-conversion" assignment strategy develops detailed incremental plans for converting part or all of the A/G radio system to a future architecture.

Reports. spectrumProspector can generate a wide variety of map displays and reports. One key output is a time-sequenced listing of all the radio conversions and/or retunings needed to carry out an incremental frequency plan.

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The MITRE Corporation’s Center for Advanced Aviation System Development, under sponsorship of the Federal Aviation Administration (FAA), has developed the Terminal Area Route Generation, Evaluation and Traffic Simulation (TARGETS) Noise Screening Tool that integrates noise impact screening directly into the design process for procedures and airspace. By enabling procedure designers to consider noise impacts early in the design process, the TARGETS Noise Screening Tool saves time and money. The tool uses the Integrated Noise Model (INM) noise computation engine, which is the FAA and international standard for assessing noise impacts in the vicinity of airports.

Users of the TARGETS Noise Screening Tool have access to all of the standard features of TARGETS, including easy import and manipulation of flight track data, simple route and procedure creation tools, and terrain and image overlays. The user-friendly Noise Screening Wizard guides users in setting up baseline and alternative scenarios for noise analysis.

The tool provides clear comparisons between baseline and alternative cases and will display color-coded points and areas indicating changes in noise levels and their magnitude.

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Unmanned Aircraft Systems

Unmanned Aircraft Systems (UASs) have the potential to transform air transportation in the United States. The unique characteristics of the vehicles themselves (size, speed, endurance) will enable entirely new users of the national airspace system (NAS) to emerge. However, the transformational nature of UASs extends beyond the unmanned vehicles themselves.

To better understand the potential impact of UASs on the current and future NAS, operational scenarios for civil and commercial uses of UASs were developed, and potential impacts are being identified through modeling, simulation and visualization. Ongoing research is addressing the issues surrounding the “see and avoid” requirement for operation in the NAS. The potential role of the Traffic Alert and Collision Avoidance System (TCAS) and new technologies for small autonomous aircraft to reliably detect and avoid collisions are among the areas under investigation.

The technologies being developed to allow UASs to operate routinely in the NAS (collision avoidance systems, digital communication architectures, information sharing networks, alternative fuels, and autonomous controls) are likely to be adopted by manned systems. Thus UASs are likely to have a significant impact across all users of the future NAS.

The MITRE Corporation's Center for Advanced Aviation System Development is conducting research and analysis on many of the important issues surrounding the integration of UASs into the NAS.

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User Request Evaluation Tool (URET)

The User Request Evaluation Tool (URET) is a system developed by The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD). It provides decision-support capabilities for en route air traffic control, including aircraft trajectory modeling, aircraft and airspace conflict detection, flight data management, and strategic planning capabilities. Under the Federal Aviation Administration’s Free Flight Program, URET has been deployed to several Air Route Traffic Control Centers and will complete National deployment by 2006.

URET Capabilities: URET combines real-time flight plan and radar track data with site adaptation, aircraft performance characteristics, and winds and temperatures aloft to construct four-dimensional flight profiles, or trajectories. For active flights, it also adapts itself to the observed behavior of the aircraft, dynamically adjusting predicted speeds and climb and descent rates based on the performance of the flight as it is tracked through en route airspace.

URET’s predicted trajectories are used to continuously detect potential aircraft conflicts up to 20 minutes into the future and to provide strategic notification to the appropriate sector.

By contrast, earlier systems had a much shorter, or tactical, "look-ahead" capability. Trajectories also provide the basis for the system’s trial planning capability, which allows the controller to check a desired flight plan amendment for potential conflicts before a clearance is issued. The controller can then construct the amendment from a trial plan with the click of a button. The controller interface to these detection and resolution capabilities supports flight data management and task prioritization using both text and graphic displays. Quick access to system functions and entry of flight plan amendments are accomplished using a point-and-click interface.

System Development Model: Since the first URET prototype system was installed at the Indianapolis Air Route Traffic Control Center in 1996, it has undergone substantial upgrades. System capabilities were developed using an evolutionary model. At each step, enhancements were introduced to teams of operational personnel and evaluated under simulated and live traffic conditions. Upgrades and refinements were added to the system accordingly. This close interaction between the operational personnel in the field and scientists and engineers at MITRE/CAASD is at the heart of the collaborative evolution that has made URET a successful program and a key component of the National Airspace System.

Operational Benefits: URET capabilities provide many operational advantages to both the controller and the airspace user. Overall, the system enables more efficient routes and altitudes to be flown because of the accurate trajectory and conflict information it provides. Strategic problem identification also enhances safety and decreases uncertainty in the long-term effects of flight plan amendments. Furthermore, URET enables the enroute controller to better handle anticipated growth in the volume and complexity of air traffic.

Current Activities: MITRE/CAASD continues to build upon the core components of URET—its trajectory modeling and conflict probe functions—to develop the next set of decision-support capabilities at the sector: problem resolution for aircraft and airspace problems, assistance for executing traffic flow initiatives, and support for handling traffic under severe weather conditions. Lessons learned are incorporated into plans for longer-term research and evolution of air traffic management capabilities in the United States and other countries seeking to modernize their systems.

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The WakeViewer Data Visualization Tool, developed at The MITRE Corporation’s Center for Advanced Aviation System Development in collaboration with The Volpe National Transportation Systems Center, is a data analysis and scenario presentation software application that plots and visually queries wake turbulence data collected by the Federal Aviation Administration. By combining several plots of measured pulsed lidar data with associated weather and operating environment data, it enables a multidimensional illustration of these factors and a better understanding of wake turbulence behavior. This tool assists the user in developing and responding to research questions in identifying and analyzing outlier data.

As a data analysis tool: This software has the ability to filter the data, rich with geometric, aircraft and operating environment parameters, as well as an innovative ability to visually filter based on geometric selection. In its main interface, WakeViewer displays:

- Positional scatter plots detailing lateral transport bounds, glide slope locations, and ground clutter profiles
- Detailed data statistics with respect to selected filters (e.g. total wakes, fleet mix, associated weather, etc.)
- Wake tracks within an isometric runway view for geometric context
- Lateral transport histogram with associated probabilities
- Crosswind histogram

WakeViewer provides the researcher with further information on wake behavior via additional plots (such as transport distances by age or crosswind, scroll-through time series plots, and current vs. proposed separation standard comparison plots) as well as the rigorous ability to filter data based on data attributes:

- Lateral transport minima/maxima
- Wake age and measured circulation
- Lidar scan azimuth
- Aircraft weight class and approach path
- Measurement quality attributes

As a communication tool: WakeViewer exports a data file, which combines the filtering ability with the power of the PAVE (Portable Aviation Visualization Environment) virtual reality setting. This allows the viewer to observe single or multiple wake tracks from innumerable perspectives such as from the cockpit of a trailing aircraft or from a stationary position.

The WakeViewer application, designed in MATLAB®, is completely stand-alone with the installation of the MATLAB® Component Runtime Software. The input data format requires a specific database format, but is flexible to accept varying dimensions of data content.

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As the Federal Aviation Administration (FAA) heads towards the Next Generation Air Transportation System (NGATS), aircraft will be assigned to Required Navigation Performance (RNP) area navigation (RNAV) routes and have modern avionics that include Flight Management Computers (FMCs) that are capable of executing Required Time of Arrival (RTA) instructions. The FMCs will also be able to downlink Estimated Time of Arrival (ETA) and 4D Intent information.

The FAA’s Roadmap for Performance-based Navigation calls for enhanced reliability, repeatability, and predictability via use of RNAV/RNP and for reduced workload and improved productivity. Aircraft flying RNP/RNAV routes have improved predictability and repeatability so that use of time domain information such as ETA or RTA can be used to reduce the controller's workload and improve overall productivity. For the mid-term, the Roadmap mandates “...procedures with 3D RNP and time of arrival control” for RNAV arrivals. Because of these identified needs, The MITRE Corporation’s Center for Advanced Aviation System Development (MITRE/CAASD) is conducting research via lab prototypes that leverage the avionic capabilities of modern aircraft in a way that time domain control can be seamlessly integrated into the Air Traffic Control (ATC) system.

The concept for using RTA involves new ground automation that will receive or calculate ETAs for the aircraft of interest. An initial local schedule is developed and analyzed for the predicted separation at a given point in space. This can be done in units of time or distance. The schedule is then adjusted as needed so that the predicted inter-aircraft spacing meets the desired spacing. Any aircraft that require a change in the local schedule will then receive RTAs that meet the objective. The RTA clearances will be voiced by the controller to the respective aircraft. The mid-term concept does not depend on data link but could take advantage of the capability if it were available. Other aircraft are given timed-speed control commands (voiced by the controller) to achieve the same effect of an RTA so that the concept can work in a mixed-equipage environment.

CAASD’s research involves (a) use of time-domain control by ATC personnel, (b) the required accuracy of the ETAs, including use of down-linked ETA information and/or ETAs calculated from surveillance data, (c) the robustness of the concept, i.e., under what conditions (geometry, wind uncertainties, etc.) can the concept be expected to provide benefit, and (d) the appropriate computer human interface (CHI) for the controller. The concept is currently being examined for application in the terminal area for merging and sequencing of aircraft on RNP/RNAV arrival routes and approaches.

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