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Research Portfolio for the Next Generation Air Transportation System

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RESEARCH PORTFOLIO FOR THE NEXT GENERATION AIR TRANSPORTATION SYSTEM

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The Next Generation Air Transportation System (NextGen) poses changes in roles and responsibilities between pilots and air traffic control (ATC) specialists as the allocation of function increasingly orients automation, technology, and procedures toward airborne separation assurance. The discipline of human factors is in a critical position to mature research concepts and prototypes, and transition those capabilities to the flight deck and in ATC. A research portfolio is required that aligns NextGen objectives with research goals, programs, and projects to resolve human performance issues, ensure human-system integration, and achieve targeted outcomes.

Introduction

The Federal Aviation Administration (FAA) in concert with other government organizations work with the Joint Planning and Development Office (JPDO) in defining the Next Generation Air Transportation System (NextGen). NextGen provides a vision to increase significantly the capacity of the National Airspace System (NAS) while ensuring safety in aerospace operations and decreasing the cost of system operations. NextGen poses changes in roles and responsibilities between pilots and air traffic control (ATC) specialists as the allocation of function increasingly orients automation, technology, and procedures toward airborne separation assurance. Pilot and aircraft-related human factors issues are addressed through the FAA Flight Deck human factors research program including aircraft maintenance and system integration. Controller and ATC automation issues are the responsibility of the FAA ATC/Technical Operations (ATC/TO) research program.

This paper provides a description of NextGen, an assessment of research goals relating to the roles of human operators, a description of two FAA human factors research programs, and an overview of the research portfolio for these two programs necessary for ensuring efficacious human performance associated with new technologies, automation and procedures.

NextGen Capabilities

The JPDO identified eight key capabilities as the framework for NextGen (FAA, 2007). These consist of the following:

- Aircraft trajectory-based operations involve managing daily operations based on aircraft trajectories and adjusting airspace structure to meet user needs and government requirements.
- Equivalent visual operations are based on providing critical information necessary to navigate without visual reference and maintaining safe distances from other aircraft during non-visual conditions.
- Weather assimilated into decision-making should provide a common understanding of weather conditions to all pilots, controllers and other users.
- Broad-area precision navigation involves providing navigation services to enable aircraft operations in nearly all operational conditions.
- Net-enabled information access means quick access to useable information on demand by users in the air and on the ground.
- Performance-based services necessitate an agile and resilient transportation system having multiple service levels for a wide range of users and services tailored to individual needs.
- Super-density operations involve peak throughput performance at all airports, large and small.
- Layered, adaptive security provides early detection of threats with appropriate intervention using risk-based screening.

Research Goals

To support the JPDO vision for NextGen, the FAA research and development (R&D) program developed a set of ten R&D goals (FAA, 2007). These goals are used to align the near-term critical safety and capacity operational needs of the FAA with the research needed for ensuring development of NextGen.

Of these ten R&D goals, four are supported in common by the Flight Deck and ATC/TO human factors research programs, and the ATC/TO program supports an additional R&D goal. The four goals supported by both programs and their definitions consist of the following:

- Human-centered design means that aerospace systems adapt to, compensate for, and augment the performance of human operators.
- Self-separation is defined as no accidents and incidents result from aerospace vehicle operations in the air or on the ground.
- Situational awareness means having common, accurate, and real-time information on operations, events, crises, obstacles and weather.
- World leadership refers to the FAA being the globally recognized leader in aerospace technology, systems and operations.

In addition, the ATC/TO research program supports a fifth R&D goal, which is high quality teams and individuals refer to the best-qualified and trained workforce in the world.

Baseline Research Programs

Flight Deck Human Factors Research Program
The Flight Deck program helps achieve FAA goals for increased safety and greater capacity by:

- Developing more effective methods for pilot, inspector, and maintenance technician training.
- Enhancing the understanding and application of error management strategies in flight and maintenance operations.
- Increasing human factors considerations in certifying new aircraft and in equipment design and modification.
- Improving pilot, inspector, and maintenance technician task performance.
- Developing methodologies to identify and mitigate risk factors in automation-related operator errors.
- Developing requirements, knowledge, guidance, and standards for design, certification, and use of automation-based technologies, tools, and support systems.

These program outcomes are realized through a range of program outputs. In general, these outputs provide the research foundation for FAA guidelines, handbooks, advisory circulars, rules, and regulations that help to ensure the safety and efficiency of aircraft operations. The program also develops human performance information that the Agency provides to the aviation industry for use in designing and operating aircraft and training pilots and maintenance personnel.

ATC/TO Human Factors Research Program

The ATC/TO program supports FAA strategic goals for increased safety, greater capacity, and organizational excellence by developing research products and promoting the use of those products to meet the future demands of the aviation system. The program generates requirements for human interface characteristics of the next generation of air traffic controller workstations. It is enhancing our understanding of the role that ATC supervisors play in mitigating operational errors. The program is also providing material to reduce incidents associated with the performance of controllers, system maintainers, and others who fill important safety roles. In addition, researchers are determining effective methods to present weather information to air traffic specialists for severe weather avoidance, developing methods to select controllers so that the applicant screening process is valid, reliable, and fair, and improving human-system integration in a manner that allows controllers to manage an increased number of aircraft in the sector while reducing task loading

These program outcomes are supported through various program outputs. The ATC/TO program provides leadership and products to motivate the evolution of the NAS to assure that the human component of the system will reliably perform to meet the needs of the flying public. Outputs include:

- Air traffic workstations and concepts that increase productivity of the workforce by identifying key workload factors that must be mitigated to enable the humans in the system to manage the traffic flow in the future NAS.
- Evaluations of candidate technologies that purport to provide a specified human-in-the-loop performance level or safety benefit when used by the ATO workforce.
- Transformation of the safety culture through research in the Technical Operations community to identify the effective interventions that are needed to move the ATO toward a Just Culture.
- Personnel selection criteria to enhance the efficiency and effectiveness of the screening process for air traffic controllers.

Research Portfolio for NextGen

The human factors research portfolio for the future or next generation system is based on definition of research priorities for the two programs and synchronization of programs to address substantive air-ground integration issues. Research priorities are defined in terms of NextGen Operational Improvements time-phased through 2015. This section addresses priorities within each program, and the next section highlights an example key air-ground integration challenge.

Flight Deck Portfolio

Research will examine effective roles for pilots and how those roles are best supported by allocation of functions between human operators and automation. This includes determining how new ways of managing 4D trajectories will change the timely sharing and use of information for seamless transitions across phases of flight. Compatibility of air and ground automation and procedures assessed through simulation ensures effective human-system integration including variable spacing requirements with mixed aircraft types in transition to and from self-separation airspace. Human-automation research needs include the following:

- Deciding the appropriate role of the pilot relative to transitions when automation is in control.
- Making 4D trajectories efficient with fair criteria for negotiations and deviations.
- Shifting separation responsibility between pilot and controller under different operational situations.
- Setting priorities for net-centric information pushed to the pilot's attention or requiring the pilot to pull information via request.
- Detecting and recovering from pilot errors, and managing distractions.
- Training pilots to assure adequate understanding of automation functions and limitations.
- Developing advanced methods to certify pilots and automation.

Human factors assessments are needed on new information requirements to allow human operators to perform new tasks safely and effectively. Such as in the context of self-separation in conjunction with area navigation, we need to move toward Required System Performance and understand how information should be displayed, communicated, and supported by decision support tools (DSTs).

Design of DSTs poses questions about what automation tools are needed to perform new pilot tasks. This should address how we can avoid the problems of the past regarding mode errors and clumsy automation. Automation design tradeoffs should consider different failure modes.

Incremental transitions to accrue operational improvements will include performance and workload assessments to ensure satisfactory levels during all phases of intended usage, i.e., normal, non-normal and emergency operations. Error management will be researched during the design and implementation of equipment, procedures and training to minimize error tendencies and facilitate error capture, mitigation or avoidance.

There are numerous activities necessary to ensure accruing intended capacity benefits from NextGen Operational Improvements. Initial air-ground integration simulations need to be planned and conducted to quantify human performance in terms of workload, situational awareness, and task performance at increasing capacity levels and in mixed equipage environments. This effort intends to support several NextGen Operational Improvements including:

- Self-spacing, merging and passing in en route airspace is allowed under certain conditions in certain airspace via cockpit display of traffic information (CDTI) and automated dependent surveillance-broadcast (ADS-B).
- Procedures based on required total system performance (RTSP) for less than 3 mile separation are implemented.
- Trajectories are exchanged via data communications.

Research also needs to investigate how pilots and controllers would use probabilistic weather information to reduce delays. A central weather challenge is having a standardized database that can be effectively tailored to meet the different needs of varied users. This effort aligns with several NextGen Operational Improvements:

- Timely and accurate weather information is available to all automated decision support tools. Improved weather information, planning, and timing enable more efficient, less conservative routing, saving time and money. Also improves safety by avoidance of convective weather.
- High altitude trajectories are supported through improved weather sensing and data fusion.
- Accurate, high fidelity weather information increases system capacity and efficiency by minimizing unavailable airspace due to convective and winter weather. Aircraft navigate tactically around weather based on aircraft equipage and pilot capability.
- Improved weather predictions are provided to improve access to non-weather impacted airspace and minimize re-routing around hazardous weather.

Procedural requirements need to be assessed for use of CDTI-assisted visual separation for increasing arrival and departure capacity including during instrument meteorological conditions. This would support several NextGen Operational Improvements including:

- In-trail separation is reduced to near visual flight rules (VFR) levels for single runway departure operations using ground based wake vortex prediction and detection, CDTI, and ADS-B.
- In-trail separation is reduced to near VFR levels for converging and closely spaced parallel runways based on ground based wake vortex prediction and detection, CDTI, and ADS-B.

The research program will develop plans addressing human performance requirements in transitions to airborne separation assurance and self-separation consistent with the NextGen Concept of Operations. This includes total system performance requirements, human error reduction, and mixed equipage with the effort supporting such Operational Improvements:

- Aircraft-to-aircraft separation is delegated to the flight deck in oceanic airspace via CDTI and improved CNS (lower RTSP) and oceanic automation (satellite, aircraft, ground surface).
- Aircraft-to-aircraft oceanic longitudinal and lateral spacing is reduced to 15 X 15 nm by use of RNP, ADS/CDTI and data communications.

Additional research initiatives involve investigating efficient and performance enhancing training methods for pilots in mixed fleet flying, development of training guidelines for mixed fleet (mixed aircraft platform) flying, and validating methods to assess the financial cost of Flight Operations Quality Assurance (FOQA) events extensible to NextGen technologies.

ATC/TO Portfolio

Research will examine the roles of air traffic controllers and maintainers to ensure safe operations at increased capacity levels and how those roles are best supported by allocation of functions between human operators and automation. The concepts being proposed by the JPDO indicate that the roles and responsibilities of air traffic controllers may change significantly if there is increased reliance on automation for conflict monitoring and if separation functions migrate to the aircraft flight deck. This research will support further development of JPDO concepts of operation by addressing human-system integration and human performance issues such as:

- Deciding the appropriate role of the controller relative to the automation.
- Ensuring that there is unambiguous transfer of separation responsibility between ground and flight deck elements of the system as aircraft make the transition between different types of airspace.
- Making appropriate use of automation to aid the service provider in airspace segments where there are variable separation criteria.
- Avoiding the design of automated systems that are “brittle” and leave the service provider with inadequate clues regarding automation failures.
- Preparing for degraded system modes so that safety can be maintained under abnormal and off-normal conditions.
- What net-centric information should be called to the controller’s attention (“push”), what information made routinely available, and what information requires request by the controller (“pull”)?
- What types and what frequency of human errors (slip, mistake, memory, mode, etc.) can be expected, by which human operators, and in what interactions with the automation?
- What controller training is needed to assure adequate understanding of functions and limitations of automation and decision aids?
- How should displays and procedures support controllers for communicating with computerized planners and other decision aids?

For new technologies, this research will include developing requirements and procedures for Air Traffic Management (ATM), requirements and prototypes for human-system integration, and human-system performance measures.

A range of specific activities is anticipated. Dispatcher and traffic management specialist information distribution requirements and ATM procedures will need to be assessed for collaborative decision-making including in inter-facility network-enabled operations. This effort intends to support NextGen Operational Improvements including:

- RTSP-based Traffic Management Initiatives (TMI) allow "Multiple TMI what-if analysis" and are incorporated into TFM automation (Evaluator Increment II).
- Execution of Flow Strategies - active flight with "GO-Button," is incorporated into TFM and en route automation and enabled via net-centric architecture to implement a TFM rerouting strategy through issuing aircraft-specific reroutes to sector teams. Reroutes are sent electronically to the Sector conflict probe and Trial Planning capability and assessed for near-term problems and implemented as flight plan amendments; reduced controller and pilot workload.

Human-system integration requirements for research concepts and prototypes will be developed at different maturity levels through simulations and field demonstrations. This will support NextGen Operational Improvements including:

- All high altitude en-route aircraft are managed by 4D trajectory.
- Arrival scheduling and sequencing tools are used to flow aircraft from en route airspace to arrival runways at OEP airports.
- Multiple levels of service are offered in high-density terminal, en route, and oceanic airspace with service level dependent on RTSP.
- Tower functions are remote to distant facilities serving smaller airports on a 24-hour basis (virtual towers).

Additional research initiatives involve expanded use of proactive human error analysis techniques to include early investment analysis and requirements decisions for new NextGen technologies, application of proactive human error analysis techniques to define and assess TO maintenance procedures for new NextGen technologies and net-centric operations, and assessment of the impact of new NextGen technology on selection and training.

Initial human-system performance measures need to be developed to compare alternative concepts, technologies, and procedures in surface traffic management. This supports several NextGen Operational Improvements:

- Aircraft and ground vehicle movement on airports in low visibility conditions is guided by moving map displays, CDTI, and ADS-B at some airports.
- Aircraft and ground vehicle movement on airports in low visibility conditions is guided by moving map displays, CDTI, and ADS-B at OEP airports.
- A Surface Management System is used to generate data linked outbound taxi instruction prior to pushback

Air-Ground Integration Challenges

Integration of air and ground capabilities poses challenges for pilots and controllers. A central core human factors issue is ensuring the right information is provided to the right human operators at the right time to make the right decisions.

The FAA Human Factors research program has historically been segregated by the topic areas of air traffic and flight deck. The trend in aviation indicates a need to blend certain elements of the two programs to address Air-Ground integration. Both the air and ground sides of the aviation system need to share intent information. The concept of trajectory management implies that a flight plan will become a performance contract that will be executed by the flight deck but protected by the air traffic system. There are multiple parameters in aviation such as weather, unanticipated traffic, sudden denial of airspace, emergencies, and a myriad of other factors that will require close monitoring. Even a simple factor such as aircraft ground speed may become a managed factor to meet trajectory expectations that must be balanced by other concerns such as fuel consumption and schedules. The safety factors that primarily have an impact on separation assurance must be jointly approached by both the flight deck and air traffic research communities. The increased levels of automation and new enabling technologies that will likely transform the NAS in the future will bring new and interesting human factors challenges.

The FAA reported on challenges regarding changes in separation standards (2006). The Research, Engineering and Development Advisory Committee (REDAC) examined how to reduce separation standards without compromising safety and developed recommendations for research to facilitate the reductions. The review found that the next generation system poses new roles and responsibilities for pilots and controllers and the automation that supports them; will provide increased situational awareness on board the aircraft providing more timely and accurate information including intent of nearby vehicles; the potential through effective system design for fewer unexpected deviations; and new backup systems will deal with system failures potentially with lesser performance capability than the system being backed up. In addition, the REDAC found that as surveillance, navigation and communication performance increase including communication of intent information, separation standards will be driven more by the need to accommodate system failures than by variations in nominal system performance.

REDAC findings are being addressed in both the baseline research programs and as part of future research planning. Ongoing research efforts support human factors guidelines for the design of instrument procedures including the development of future procedures based on area navigation (RNAV) and the required navigation performance (RNP) of the aircraft. Execution of robust and leveraged research plans will be commensurate with program funding to address the most critical issues.

Other ongoing research efforts address operational and design constraints effecting human error detection and recovery, error prediction, and managing distractions in order to ensure continued situation awareness by the air crew. Training of pilots and controllers can be designed to ensure adequate understanding of functions and limitations of automation and decision aids important to advanced methods for certifying automation and human operators.

The knowledge base for understanding and defining effective roles for pilots and controllers in next generation systems and how those roles are best supported by allocation of functions between human operators and automation is framed relative to the Operational Improvements envisioned in NextGen. These Operational Improvements including provision for self-spacing, merging and passing in en route airspace via CDTI and ADS-B with procedures based on RTSP for less than 3-mile separation. Lateral and in-trail separation would be reduced to near VFR levels for single runway and for converging and closely spaced parallel runway operations using CDTI, ADS-B and wake vortex ground detection. Aircraft-to-aircraft separation would be delegated to the flight deck in oceanic airspace with reduced longitudinal and lateral spacing via RNP, ADS/CDTI and data communication.

Proposed research efforts will leverage TCAS and CDTI capabilities to provide data-driven guidance on their integration (such as to display traffic position, identification, alert status, data quality, and air/ground status) to include new ways of managing 4D trajectories that could change the timely sharing, display and compatible air and ground use of information including variable spacing requirements with mixed aircraft types and equipage. Human factors challenges for display design include symbology and phraseology, recognizing and communicating pilot/controller intent, traffic directionality, automated coordinated maneuvers with other aircraft, vertical state depiction, geometric altitude use and depiction, panning and zooming, decluttering, alerting, velocity vectors, degraded information, continuous vs. part-time information display, procedures, workload, and workflow.

A system approach to air-ground integration needs to address how to transition from current operations to new concepts taking into account changes in responsibilities and liabilities. Interoperability of air and ground DSTs necessitates synchronization of conflict probe look-ahead times, 4-D intent information, and alerting functions for CDTI and Precision Runway Monitor for closely spaced parallel approaches. Pilots and controllers need a shared understanding of how procedures change in transitions across different types of airspace, e.g., from a self-separation regime to shared separation to terminal environments. Procedures may also change relative to mixed equipage and aircraft types (such as Very Light Jets) and how air and ground systems will communicate and display aircraft capabilities.

One other example of an air-ground challenge is highlighted by an assessment of the predictability of operations using different flight deck systems. Alexander (2006) listed differences with flight management computer (FMC) systems. These include lack of standardized turn performance when transitioning between straight legs, lack of a standard way to apply initial segments of RNAV departure procedures and the resulting disconnect with procedure design criteria, and variability between FMCs when transitioning to different phases of flight. These differences are associated with different FMC avionics and airframes. The challenge involves how FMC system variability might interact with potential sensitivity of ground-based automation for trajectory estimation and conflict prediction.

Disclaimer

The views expressed are those of the authors and do not represent the FAA.

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