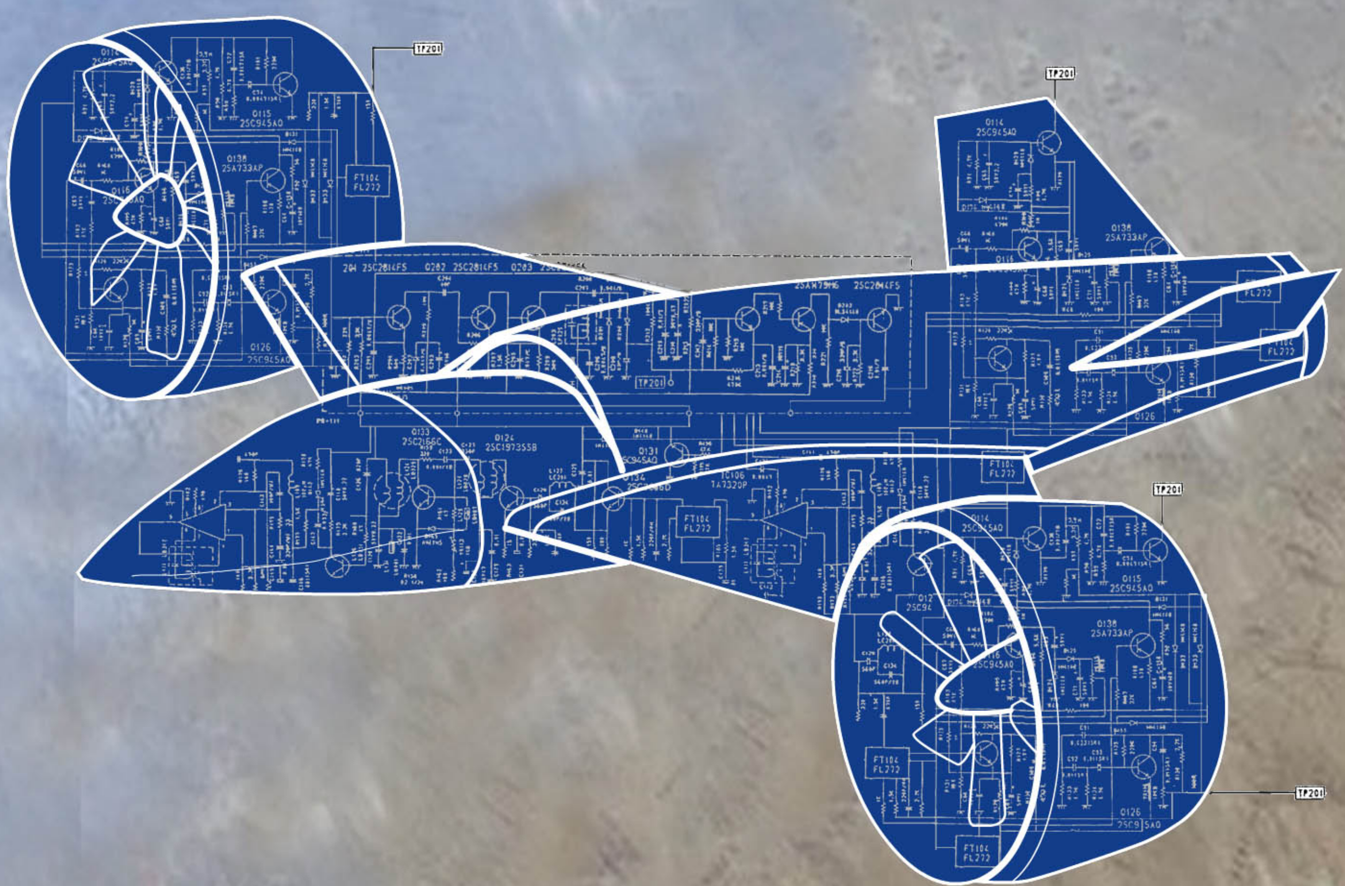
Next Generation Air Transportation System

NextGen UAS Research, Development and Demonstration Roadmap



Version 1.0
March 15, 2012

Next Generation Air Transportation System
Joint Planning and Development Office

Next Generation Air Transportation System

Unmanned Aircraft Systems
Research, Development and Demonstration Roadmap

Table of Contents

Executive Summary

This is the first report of progress in producing a NextGen Unmanned Aircraft Systems Research, Development and Demonstration Roadmap (NextGen UAS RD&D Roadmap). The activity was established to enable a responsive, efficient, timely, coordinated multiagency Research and Development (R&D) effort that will enable the U.S. to realize fully the benefits of Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS).

The use of UAS dates from the earliest days of flight. UAS today play an increasing role in many public missions such as border surveillance, wildlife surveys, military training, weather monitoring, and local law enforcement. However, expansion of domestic UAS operations has been inhibited by lack of a common understanding of what is required to safely and routinely operate UAS in the NAS. Challenges such as the lack of an onboard pilot to see and avoid other aircraft and the wide variation in unmanned aircraft missions and capabilities must be addressed in order to fully integrate UAS operations in the NAS in the NextGen timeframe.

This report represents a significant effort on the part of the Next Generation Air Transportation System (NextGen) partner agencies to establish a multiagency roadmap of the R&D necessary to enable routine operations of UAS in the NextGen NAS. This initial report is intended to accomplish the following objectives:

- Document an initial set of critical R&D challenges that need to be addressed to enable routine access for UAS in the NextGen NAS
- Develop an approach to linking the R&D activities of the partner agencies with the R&D needs of the FAA to support integration of UAS in the NAS
- Establish an approach to coordinating R&D activities of the participating agencies in order to address those challenges
- Identify relevant ongoing and planned R&D projects to serve as a baseline for the NextGen UAS RD&D Roadmap[1]
- Set forth a series of next steps toward achieving a responsive, vetted roadmap, monitoring progress, and identifying actions needed

The Office of Management and Budget recently tasked the NextGen partner agencies to develop a strategic, multiagency, NextGen UAS RD&D Roadmap with facilitation and assistance from the Joint Planning and Development Office (JPDO). The primary objective was to identify the most critical technology issues involved in establishing a plan for UAS operations. The results are contained in this document, which will serve as a baseline for further development of the Roadmap.

The roadmapping activity is intended to assist the FAA in identifying and providing information needed to enable routine UAS access in the NextGen NAS. The Roadmap will also assist the R&D performers in the partner agencies to share information, enabling the agencies to make faster progress in addressing the critical R&D challenges; to capitalize on the research

[1] All references in this document to a Roadmap, unless otherwise specified, refer to the NextGen UAS RD&D Roadmap, and not to the Civil UAS NAS Integration Roadmap being prepared by the FAA.

investments of other agencies; to consider parallel lines of research that complement one another while avoiding duplication; to allow identification of partners positioned to address specific issues most efficiently; and to identify opportunities for joint demonstrations that can enhance the value derived from those investments.

Three technical workshops were held to support this effort. Subject matter experts from the partner agencies—National Aeronautics and Space Administration, Department of Defense, Department of Commerce, Department of Homeland Security, and the Federal Aviation Administration (FAA)—contributed to four technical tracks (Communications, Airspace Operations, Unmanned Aircraft, and Human Systems Integration), depending on their area of expertise. Concurrently, each agency developed a description of their perspective on UAS operations and R&D needs, which in the case of the FAA includes a consolidated agency overview of the products that must be developed to accomplish full integration of UAS, and of categories of R&D needed to develop those products.

The road-mapping process to date has enabled the partner agencies to identify the most critical R&D challenges that must be addressed to accomplish fully integrated UAS operation in the NAS in 2025. These UAS R&D challenges by track include the following, for which initial goals are documented in the report:

Communications

- *Impact of UAS operations on NAS communication systems*
- *Ensure availability of UAS control frequency spectrum*
- *Develop and validate UAS control communication system performance requirements*
- *Ensure security of safety critical communications with UAS*
- *Design and develop UAS control datalink for allocated UAS frequency spectrum bands*

Airspace Operations

- *Develop Integrated Separation Concepts*
- *Develop Airspace Integration Safety Case/Assessment*
- *Develop Sense-and-Avoid Sensors and Fusion*
- *Develop Separation Algorithms*
- *Assess Availability/Quality of Surveillance Data*
- *Develop Safe and Efficient Terminal Airspace/Surface Operations*

Unmanned Aircraft

- *State Awareness and Real Time Mission Management*
- *Airframe Certification*
- *Precise Location and Navigation*
- *UAS Avionics and Control Systems Certification*

Human Systems Integration

- *Display of Traffic/Airspace Information*
- *Effective Human-Automation Interaction*
- *Pilot-Centric Ground Control Station*

- *Definition of Roles and Responsibilities*
- *Predictability and Contingency Management*
- *System-Level Issues*
- *NextGen Airspace Users and Providers – Qualification and Training*
- *Support for Future/Enhance Capability of UAS*

Since the FAA is the intended recipient of R&D addressing integrated UAS operations in the NextGen NAS, that agency's perspective is an essential part of this document. The FAA perspective provides a description of the information the FAA needs from R&D performers in order to enable fully integrated UAS operations in the NextGen NAS. This document also provides an initial analysis of which needs identified by the FAA are addressed by each critical R&D challenge.

Another objective of the Roadmap is to identify ongoing and potential coordination and cooperation among the research performers of the partner agencies. The document provides a summary of such ongoing collaboration, including promising opportunities for joint demonstrations in which the participation of multiple partners would yield significant benefits.

This report also describes a set of actions to be taken in 2012 that will accomplish the following:

- Fully vet the identified R&D challenges with the FAA and with the larger community involved with UAS
- Prioritize the R&D challenges on how well they facilitate fully integrated UAS operation in the NextGen NAS in terms of urgency, importance, magnitude of effort, and required lead time
- Develop recommendations for program-specific interagency plans to address the highest priority R&D challenges. These plans will include program interdependencies and milestones, will leverage work being performed outside the partner agencies, and will identify and propose means of addressing gaps that are not addressed by current and planned R&D programs

The overall effort is intended to produce an actively managed process, rather than a static document. The present UAS RD&D Roadmap, version 1.0, serves as the baseline for future efforts. Version 2 of the UAS RD&D Roadmap, to be completed by September 30, 2012, will reflect interdependencies identified among performing agency R&D plans and programs to address the highest priority R&D challenges. Future versions of the Roadmap will be published as needed to reflect the evolution of this effort as multiagency R&D plans are executed, challenges are successfully addressed, and new challenges emerge.

Chapter One

Introduction

Purpose

Enabling the integration of Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS) is an important consideration in the planning and implementation of the Next Generation Air Transportation System (NextGen), the multi-disciplinary effort that will provide a host of operational, technical, economic, and environmental opportunities and challenges for all NAS users. An unmanned aircraft is generally defined as an aircraft operated without the possibility of direct human intervention from within or on the aircraft (with the exception of optionally-piloted aircraft). UAS operations use a system architecture that includes the unmanned aircraft; control and communications elements; the human element (pilot and supervisor and support, such as transport, launch, and recovery); and payload, including sensors and communications relay.

UAS have evolved from simple radio controlled model airplanes to sophisticated aircraft that today play a unique role in many public missions such as border surveillance, weather monitoring, military training, wildlife surveys and local law enforcement, and have the potential to do so for many civil missions as well. However, the current NAS is designed around the use of manned aircraft, and UAS access to the NAS, especially for commercial operations, remains restricted. The Federal Aviation Administration (FAA) currently allows UAS operations on a case-by-case basis under an FAA Certificate of Approval or Waiver (COA), based on the capabilities of the particular UAS. Public entities—law enforcement, Department of Defense (DOD), Department of Homeland Security (DHS) and universities—may gain access to civil airspace for a UAS by applying for a COA. Special airworthiness certificates are available to civil operators for experimental purposes, which unfortunately precludes operations for compensation or hire.

The FAA conducts a comprehensive operational and technical review of each application and issues a COA, which may include provisions or limitations to ensure the UAS can operate safely. Each COA authorizes an operator to use a defined airspace for a specified period of time (up to one year). In 2010, the FAA issued COAs to 95 users for 72 different aircraft types, and as of December 1, 2010, there were 273 active COAs. UAS are treated as aircraft and are required to comply with the aircraft operating rules set forth in Federal Regulations, Title 14, Part 91. Depending on the rules specified in each individual COA, UAS may operate under both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR), in both special use airspace and non-segregated airspace.

According to industry forecasts, UAS operations will increase exponentially in a variety of key military and civil areas. About 50 U.S. companies, universities, and government organizations in the U.S. are developing over 150 different unmanned aircraft designs. Projections for 2010 to 2019 predict more than 20,000 UAS produced in the U.S., with a total of more than 35,000 produced worldwide[2]. From an operational, infrastructure and safety perspective, this presents a number of challenges due to the diversity of aircraft, control stations, levels of autonomy, and communications methods. UAS span a wide spectrum of size, endurance, and performance characteristics, often different from manned aircraft. The solutions to these challenges will affect all NAS constituencies, but they will ultimately enable seamless integration of UAS in the NextGen NAS.

In an effort to plan for the projected growth in UAS operations, the Office of Management and Budget (OMB) tasked the NextGen partner agencies to develop a strategic interagency UAS Research, Development, and Demonstration (RD&D) Roadmap, to be delivered to the by Joint Planning and Development Office (JPDO) September 30, 2011. The JPDO has an interagency focus, coordinating NextGen efforts among the FAA, the National Aeronautics and Space Administration (NASA), the Departments of Commerce (DOC), Defense, and Homeland Security, and the White House Office of Science and Technology Policy (OSTP). The legislation establishing the JPDO[3] calls for the organization to guide NextGen research and development by coordinating goals, priorities, and research; facilitating technology transfer, and creating multiagency roadmaps. The same legislation calls for the JPDO to ensure that NextGen can handle a wide range of aircraft operations, such as UAS, to the same high level of safety in the NAS that the FAA demands today. In this context, the JPDO is facilitating and coordinating steps to make sure that all stakeholders have an understanding of the collective agency plans, and to develop clear strategies and requirements for UAS in a NextGen environment. The ultimate goal is to enable a responsive, efficient, timely, coordinated multiagency research and development (R&D) effort that will enable the U.S. to realize fully the benefits of UAS operations in the NAS.

The NextGen Concept of Operations (ConOps)[4] was developed by the JPDO to meet the goals and objectives established in the Integrated National Plan for NextGen[5] established in response to the Century of Aviation Act.

The ConOps is based on the application of advanced technologies and procedures to increase air traffic management (ATM) system capacity and manage variations in demand and aircraft types, both manned and unmanned, seamlessly civil and public operations. It identifies the following eight major NextGen concepts to achieve NextGen goals and objectives:

- Net-Centric Operations (NCO) - Network-Enabled Information Access provides secure information access.
- Performance Based Operations and Services applies minimum performance levels through regulations and procedures to maximize capacity in congested airspace.

---

[2] World Unmanned Aerial Vehicle Systems, 2010 Market Profile and Forecast, Teal Group Corporation.

[3] U.S. Congress, "Vision 100 – Century of Aviation Reauthorization Act," Public Law 108-176, December 12, 2003.

[4] Joint Planning and Development Office, Concept of Operations for the Next Generation Air Transportation System, Version 3.2, September 30, 2010.

[5] U.S. Department of Transportation, Integrated National Plan for the Next Generation Air Transportation System, December 12, 2004.

- Weather Assimilated into Decision Making applies both probabilistic and observed weather information to ATM decision tools.
- Layered Adaptive Security deploys a multilayered security system to deter threats, proportional to the assessed risk.
- Position, Navigation, and Timing (PNT) Services - Broad Area Precision Navigation uses satellite navigation to accurately and precisely determine one's current location and orientation.
- Trajectory Based Operations (TBO) dynamically adjusts a flight path in space and time using a known position and intent to allow a decrease in separation and increase in NAS capacity.
- Equivalent Visual Operations provides aircraft operators with the critical visual information needed to maintain safe distances from other aircraft, terrain, and airport infrastructure during night and instrument metrological conditions.
- High-density Arrival and Departure Operations improves terminal aircraft movements.

Key features of these concepts support the integration of UAS in the NextGen NAS. The transformation from clearance-based operations to TBO increases system capacity, flow management, and efficiency. Advancements in aircraft systems allow for reduced separation and facilitate transition from rules-based operations to performance-based operations.

NCO provides the foundation for robust, efficient, secure, and timely flow of information to and from a broad community of users and individual subscribers. Embedded in NCO is Shared Situational Awareness, offering a suite of tools and information designed to provide participants with real-time aeronautical and geospatial information, communicated and interpreted electronically without the need for human intervention.

PNT services reduce dependence on costly, ground-based navigational aids by providing users with a more precise and reliable source of global positioning and timing information, allowing users to accurately and efficiently determine their orientation, course, and speed necessary to arrive at their desired destination. Real-time situational awareness integrates cooperative and noncooperative surveillance data from all air vehicles to safely navigate in the NAS.

Additional information describing the JPDO concepts for NextGen is detailed in the Joint Planning Environment, accessible at http://jpe.jpdo.gov/ee/request/home.

The Roadmap activity is responsive to the National Aeronautics Research and Development Plan[6], which cites the importance of integrating UAS into the NextGen NAS and establishes national development and demonstration objectives to that end. These objectives are intended to address the demonstration of sense-and-avoid capability for UAS operating in airspace environments ranging from low-density operations to high-density, metroplex terminal operations. The National Plan also recognizes that "achieving safe UAS integration depends on a complex set of regulatory, technical, economic, and political factors that must be addressed in an integrated and systematic fashion," hence the need for a coordinated multiagency effort.

---

[6] Executive Office of the President, Office of Science and Technology Policy, National Science and Technology Council, "National Aeronautics Research and Development Plan," February 2010

Goal 6 of the national security and homeland defense section of the plan identifies the R&D objectives for UAS integration in the NAS, as shown in Table I. The critical R&D challenges identified by NextGen partner agency R&D performers and presented in Chapter 3 are consistent with achieving the UAS objectives indicated in the National Aeronautics R&D Plan.

Table I UAS Objectives in the National Aeronautics R&D Plan

Goal	Near Term (<5 Years)	Mid Term (5-10 Years)	Far Term (>10 Years)
Goal 6 Develop capabilities for UAS NAS integration	Develop a flight safety case modeling capability including data collection methods Define the appropriate target level of safety and the process for evaluation	Validate and verify flight safety assessment capability	Demonstrate rapid, routine flight safety assessments
	Demonstrate sense and avoid capability for large UAS in low traffic environments	Demonstrate sense and avoid for full range of UAS sizes and multiple UAS in low density airspace and mixed fleet interactions	Demonstrate sense and avoid for full range of UAS in all classes of airspace including high density terminals and metroplex areas

The challenge for the JPDO and its partner agencies is how best to integrate UAS operations in NextGen. What technologies need to be developed for unmanned aircraft and related systems in order for them to operate safely among manned aircraft? What technologies need to be developed for NextGen in order to allow effective and safe management of a changing landscape of unmanned aircraft and users seeking to operate in the NAS? What knowledge must be gained regarding technological and human performance in manned versus unmanned systems to enable the FAA to develop appropriate policies, procedures, guidelines, and standards?

Interagency coordination and collaboration is challenging. Differences in terminology, priorities, and culture must be identified and dealt with in order to identify true linkages. This requires a significant investment of manpower and support at the program level. Senior leadership at each NextGen partner agency committed these resources to the effort of producing the UAS Roadmap. The outcome of that commitment was the development of a process by which the partner agencies can coordinate their research to maximize the return on investment dollars for UAS R&D, while also coordinating with the FAA to ensure that research products developed address the FAA's needs in order to accomplish full integration of UAS operations in NextGen. The process to date has enabled the partner agencies to identify the most critical R&D challenges that must be addressed to accomplish UAS operation in NextGen, to match existing and planned partner agency R&D against those R&D challenges, and to begin to map the challenges identified from an R&D performer perspective against the FAA's needs as a user of the outcomes of that R&D. The next steps in this process will enable identification of gaps in current and planned agency R&D plans that must be addressed to deliver the information needed by the FAA for crucial UAS integration decisions, and will enable development of an approach leveraging the work of all partner agencies toward the most timely and efficient delivery of needed information to the FAA.

Scope

In the face of ever-increasing budget pressures, the scope of technical challenges in UAS R&D demands that the partner agencies of the JPDO—each representing different user needs and each with a significant body of expertise and investment in UAS—work together to share knowledge and resources and to approach UAS R&D efficiently and strategically. As a result, the scope of the Roadmap was confined to UAS R&D activities performed or funded by the partner agencies and necessary for operations in a NextGen 2025 NAS. Roadmap activities were focused on capturing those R&D activities being performed by NASA, DOD, DOC, DHS, and the FAA, and to identify opportunities for joint demonstrations that may allow more information to be collected from the investment than single-agency efforts. In addition, the partners have developed a structure by which they will be able to coordinate research with one another to enable greater progress toward collection of the knowledge needed for safe and cost-effective integration of UAS operations in NextGen.

Method

The charter for the NextGen UAS RD&D Roadmap development was to create a roadmap of critical research, development, and demonstrations needed to enable routine UAS access in NextGen airspace. The primary initial objective was to identify a limited set of the most critical technology issues involved in establishing a plan for UAS operations. That objective was accomplished, and the results are documented in this report to serve as a baseline for further development of the Roadmap.

To form the basis for the Roadmap, three UAS workshops were held where agency subject matter experts contributed primarily to a single technical track depending on their area of expertise. Agencies participated in one or more of the technical tracks, based on whether they had projects supporting that track. Leadership of each technical track was decided by the participating agencies based on their strategic interests. The technical track leaders collected information relevant to their track, and led their track at each of the three Roadmap working meetings.

Concurrently with this activity, each agency developed a description of their agency's perspective on UAS operations and R&D. In particular, the FAA developed a consolidated agency overview of the products that must be developed in order to accomplish full integration of UAS and identified categories of R&D needed to develop those products.

A senior research scientist was assigned full time to the effort to provide a communication bridge among the executives and technical experts delegated from each agency. The JPDO provided support to plan and coordinate meetings, provide logistical support during meetings, and collate information for interim and final reports. The JPDO also provided contract support in gathering information on existing and planned R&D programs, projects, and demonstrations within the participating agencies, as well as relevant activities by other agencies or entities that directly affected the Roadmap. Finally, the JPDO hosted and maintained an evolving index of identified R&D programs to support the work of the technical committee.

Representatives of NextGen partner agencies—NASA, DOD, FAA, Commerce and DHS—with the JPDO providing coordination and logistical support—were responsible for the final Roadmap.

Relationship to Other UAS Planning Activities

The FAA is developing a ConOps for the integration of UAS operations in the NextGen NAS, which will provide the vision of how these aircraft will be integrated with other NAS operations in the NextGen environment. Following a standard system engineering process, the ConOps should be used to derive a set of technical, operational, regulatory, and other requirements. These concept-level requirements will aid in prioritizing research activities as well as identifying any research gaps that may exist. In addition, a ConOps provides decisionmakers a reference for assessing the feasibility of candidate concepts and their relationship to other aspects of the operational environment. The FAA's Civil UAS Integration Roadmap will define a transition from today to the integrated vision described in the ConOps, supported with R&D that will be identified through the NextGen UAS RD&D Roadmap activities.

The NASA UAS in the NAS project has provided documentation of its initial UAS Concept of ConOps to the FAA, as a prospective starting point for the FAA's development of a ConOps. The DOD has also provided operational scenarios to the FAA from the DOD UAS ConOps effort to assist with development of the FAA UAS ConOps.

NASA is currently executing a five-year, multidisciplinary UAS in the NAS research project. UAS in the NAS research activities address many of the challenges presented in this NextGen UAS RD&D Roadmap, and NASA is fully engaged in the Roadmap activity as a means of leveraging the research of other agencies and fully engaging the R&D community to accomplish program objectives.

The UAS Executive Committee (UAS ExCom), which is made up of senior executives from the FAA, DOD, NASA, and DHS, also has a role in increasing federal government UAS access to the NAS. The interests of that group may intersect at some points with those of the NextGen UAS RD&D Roadmap activity.

Beginning in December 2008 the FAA organized an ongoing series of Sense and Avoid (SAA) workshops involving the FAA, DOD, Federally Funded Research and Development Centers (FFRDCs), and industry to tackle the translation of manned aircraft requirements for "see-and-avoid" into capabilities, functions, metrics, and evaluation criteria for unmanned aircraft "sense-and-avoid." The workshops are designed to provide RTCA Special Committee (SC) 203 and other stakeholders with definitions for SAA concepts, the functions necessary to carry out SAA, identification and allocation of roles and responsibilities, and evaluation metrics, methodologies and the thresholds that need to be met to substantiate the safety of a given SAA system or approach.

The Office of the Secretary of Defense (OSD) has sponsored a variety of workshops and panels on topics relevant to operation of UAS in the NAS, such as the OSD UAS Sense and Avoid Panel and Target Level of Safety and Analysis of Alternatives efforts. The NextGen UAS

RD&D Roadmap effort coordinates with OSD to ensure that these efforts complement one another, and OSD is represented on the NextGen UAS RD&D Roadmap Planning Committee.

There are many more activities in addition to those listed above. Stakeholder focus on near-term sense-and-avoid issues is reflected in the findings of the NextGen UAS RD&D Roadmap activity presented in Chapter 3, wherein the R&D subject matter experts found that SAA issues are on target to be resolved if current and planned programs to address them are executed. Other technical areas, such as Unmanned Aircraft and Human Systems Integration, have not received as much concentrated focus, and some critical R&D challenges in those areas are not yet being adequately addressed. The NextGen UAS RD&D Roadmap can serve as an important tool in planning R&D to address the broad range of challenges that must be resolved to allow fully integrated UAS operations in NextGen.

Airspace Access

Airspace access considerations are the purview of the FAA, which is in the process of determining specific data it will require to permit routine UAS access. The R&D divisions of the NextGen partner agencies have contributed to this Roadmap with the intention of clarifying what work is possible and offering suggestions to the FAA regarding promising technologies that may support its decisions and operations. The FAA responded to a Congressional mandate by delivering a Public UAS NAS Access Plan in October 2010, and that agency is currently developing a civil UAS Roadmap. This Roadmap document does not duplicate those efforts, but instead identifies key R&D challenges, the resolution of which will be necessary to allow routine UAS operations in the NextGen NAS.

The current NAS environment was designed around the use of manned aircraft. While many procedures and principles used for manned aircraft apply to UAS, there remain significant differences in technological maturity, capabilities, acceptance, and operational experience. Performance differences between UAS and manned aircraft in a mixed-equipage operational airspace may hinder capacity of the NAS. NextGen must deal with these differences now because the demand for UAS operations, particularly by public agencies, has increased dramatically over the past few years, and is expected to continue to increase due to the unique capabilities and mission effectiveness of UAS.

In designing NextGen and planning for a substantial increase in the use of UAS, the FAA considers the most important technical challenge to be developing a safe and efficient way that UAS can operate in the same airspace as manned aircraft without creating a hazard to other aircraft or objects on the ground. For example, UAS might not have the ability to respond to Air Traffic Control (ATC)-issued instructions as quickly as manned aircraft. In addition to this communications latency, there is the possibility of a total loss of communications between the pilot and the aircraft. Such considerations are likely to introduce the need for new requirements, mitigations, and validation methods to enable safe operations.

The FAA has implemented interim policies that allow its Unmanned Aircraft Program Office and Air Traffic Organization to authorize UAS flight operations on a per-request basis. In the past five years, the FAA has issued more than 90 experimental certificates for almost 20 different types of civil UAS. Through these efforts, the FAA works with manufacturers to collect technical and operational data to help improve the UAS airworthiness certification process.

The chapters which follow describe the management concept for the NextGen UAS RD&D planning activity, the critical R&D challenges to enable UAS operations in the NextGen NAS, ongoing and planned demonstrations and collaborations, and next steps. Appendix A provides background information on UAS experience and needs of each of the NextGen partner agencies.

Chapter Two

Coordinating UAS R&D and Demonstrations Across NextGen Partner Agencies: Challenges and Approach

Background

In 2010, the Air Force Research Laboratory (AFRL), FAA, and NASA began an effort to better coordinate their R&D related to UAS. In 2011, encouraged by a request from OMB, these partners formalized their efforts, bringing in DOD researchers from the other services, as well as DOC and DHS. These partner agencies—FAA, NASA, DOD, DHS, and DOC—formed a committee of executives to develop a formal plan by which they could coordinate UAS R&D and demonstrations across these agencies. This team met frequently to develop common objectives and approaches, reported to senior leadership in their organizations to ensure buy-in, and assigned subject-matter experts to work in teams to identify challenges and to map existing work across agencies. These initial steps enabled the development of this Roadmap and a structure by which UAS R&D, as managed by researchers in the partner agencies, can be guided by an interagency understanding of what is needed to accomplish fully integrated UAS operations in the NextGen NAS, with mechanisms in place to facilitate interagency collaboration to address those needs. The research management structure in this chapter lays out the process by which this information may be used to enable coordination of UAS R&D in order to most efficiently and effectively generate the information needed to achieve UAS integration in NextGen. The resulting effort reflects a joint plan of regulators and R&D performers, and will enable closer coordination among these participants than has occurred in the past.

Challenges

Each of the NextGen partner agencies participated in this effort, reflecting a shared desire to coordinate research. As budget pressures continue, each organization must find ways to accomplish its R&D needs. Effective use of the research of other performing agencies is essential to making that happen. In addition, it is in the nature of scientists to desire communication with a larger community of researchers to advance their own knowledge and research. There is no existing venue dedicated to presentation and discussion of scientific UAS research findings; at present this is carried out as an adjunct to existing aviation meetings. The partnership formed in development of this Roadmap greatly enhances the opportunities for peer-to-peer relationship building across agencies, which is crucial to effective research collaboration on an institutional level.

However, there are understandable challenges to R&D coordination across agencies. Each organization has organized its research plans to address the needs of a specific user community. The FAA addresses airworthiness and airspace management to support safe design and operations of all aircraft in the NAS. NASA's UAS in the NAS project is focused primarily on civil access. NASA is also focused on issues associated with public access, a critical enabler for some of NASA's science mission objectives. The DOD user community has needs focused on preparing for and operating in combat environments. DHS is focused on operational missions in existing U.S. airspace and has extensive experience with UAS operations in the NAS. DOC's National Oceanic and Atmospheric Administration (NOAA) is primarily focused on enabling scientific and public missions using UAS technology to allow more cost-effective, safer operations with enhanced capabilities not possible with manned aircraft.

These different objectives and orientations mean that research activities don't line up one-for-one across agencies. Each agency has terminology developed over decades to address its specific objectives. Most notably, the FAA has a unique responsibility to ensure the safety of the flying public above all other priorities, and has a culture and institutional rules and procedures to protect that mission. The focus of the other organizations is on the operation of unmanned aircraft.

Over the course of Fiscal Year 2011, the partner agencies have organized research priorities and mapped current and planned research against those priorities. In addition, the partner agencies have developed a research management plan that will allow refinement of FAA research needs and identification of R&D programs that can address those needs. The execution of this plan will enable the R&D performers among the partner agencies to provide the FAA with critical knowledge needed to develop policies and procedures for routine UAS operations in the NextGen NAS.

Purpose

The purposes of the research management plan are twofold.
First, to ensure that R&D performers in the partner agencies:

- Share information to enable faster progress
- Conduct joint demonstrations, when possible, to obtain greater benefit from those investments
- Consider parallel lines of research that complement one another while avoiding duplication
- Enable leadership of critical research issues by the partners best positioned to address them

Second, to provide the FAA with the information it needs to enable routine UAS access in the NextGen NAS.

In some cases it is difficult to identify all R&D relevant to UAS, because not all such research is formally labeled as "UAS." For example, UAS integration requires a great deal of research in communications and sensors that is not necessarily identified as UAS-specific. Additionally, in order for the R&D performers in the partner agencies to provide the FAA with the information it needs, they must understand the FAA's R&D requirements

Because of the long timeline needed to perform R&D, the R&D community must anticipate future user needs and desires, in addition to focusing research on FAA-identified needs. Facilitating UAS access in NextGen will require that much of the needed work be performed concurrently. While the FAA develops specific guidance, the members of the R&D community must use their expertise to determine which issues they believe will be most important, and they must ensure that they are conducting the needed R&D to address those issues. Close coordination with the FAA at each stage in this process will ensure that the R&D continues to develop in ways that address the FAA's evolving requirements for management of an airspace that includes UAS operations.

Figure 1 illustrates the information flow and the role of the NextGen UAS RD&D Roadmap activity in developing the information and R&D plans to enable operation of UAS in the NextGen. As shown in the figure, in addition to the Roadmap, this process will result in coordinated multiagency R&D and demonstration plans and an agreed set of UAS R&D needs.

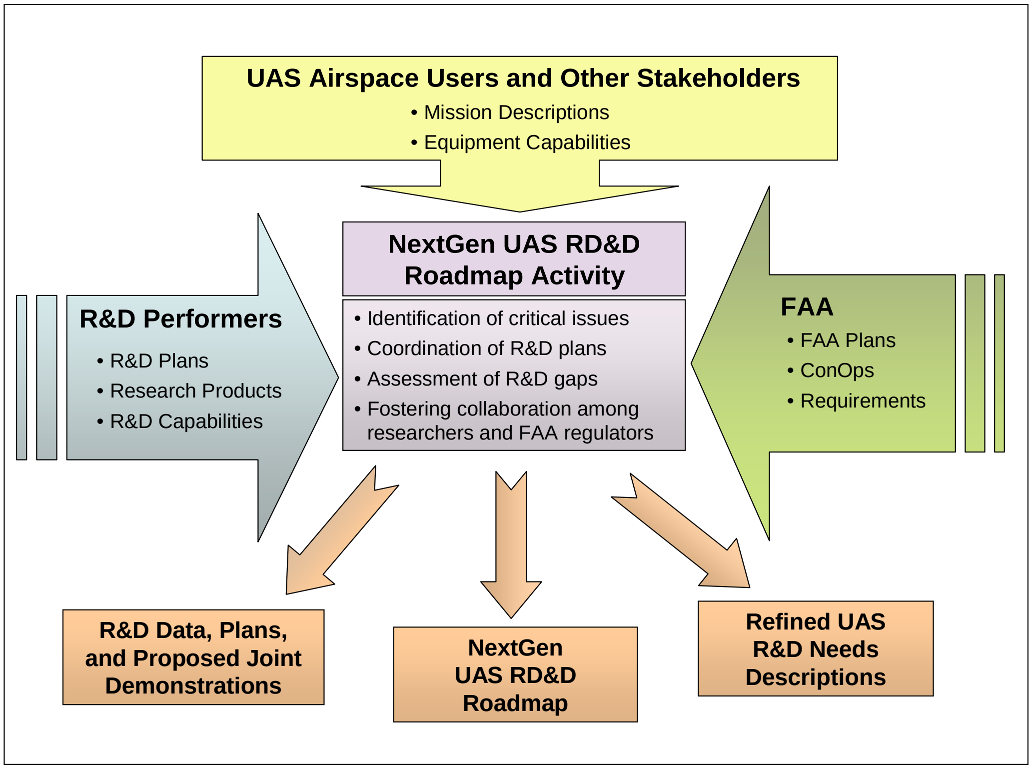


Figure 1 NextGen UAS RD&D Roadmap information flow

Relationship with FAA Offices

This research management plan is intended to be executed by the R&D performing organizations. However, at each stage of execution, it is essential to work closely with the FAA Safety, Air Traffic, and Airports offices to maximize opportunities for transfer of technology to address FAA needs. A close FAA partnership with R&D performers will allow the FAA to identify where work exists that can address their needs, as well as identify and prioritize critical gaps that partner agency investments will not meet. Because the partner agencies also represent the UAS operational community, which has additional needs not directly related to airspace management, they may choose to perform some research that does not directly serve FAA airworthiness and airspace management needs; development of advanced UAS technology to address specific missions is an example of such a need. Additionally, the R&D community takes a long-term view of UAS operations, and it may, therefore, invest in innovative technologies that are intended to enable operations not currently presented for consideration by the FAA.

Coordination Structure

Figure 2 illustrates the planned management structure to refine, periodically update, and monitor the execution of the NextGen UAS RD&D Roadmap. As illustrated, ad hoc working groups will be formed by the technical committee to address priority issues as they arise, and their recommendations will be integrated into the Roadmap using a structured engineering approach through the management structure shown.

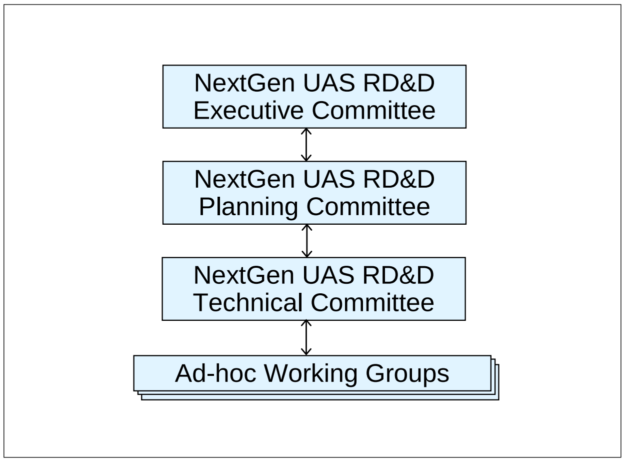


Figure 2 NextGen UAS R&D coordination structure

Three standing committees are responsible for development of the NextGen UAS RD&D Roadmap in the NextGen UAS R&D coordination structure.

The NextGen UAS RD&D Executive Committee consists of the senior executive at each partner agency responsible for identifying UAS-related R&D priorities within that organization. Their role is to provide top-level guidance to the activity, and where necessary to authorize programmatic decisions and to commit needed resources for the successful implementation of the coordinated research plan represented by the Roadmap.

The NextGen UAS RD&D Planning Committee consists of partner agency executives engaged in the management of R&D directly related to UAS. Their role is to supervise and guide the work of the Technical Committee to ensure the R&D plans align with their own agency priorities, as well as addressing the objective of enabling UAS access in the NextGen NAS. The Planning Committee will formulate recommendations to the Executive Leadership and will approve all products of the Technical Committee and ad hoc working groups prior to their submission for approval within agency or release.

The NextGen UAS RD&D Technical Committee consists of senior R&D program leaders and subject matter experts across the domains of knowledge critical to UAS integration in the NextGen NAS, as well as representatives of the FAA. This committee is responsible to ensure vetting of the R&D challenges, to organize meetings as needed and to organize and supervise ad hoc working groups to address specific R&D challenges, and to communicate the findings of those groups to the Planning Committee. The first task of the Technical Committee will be to thoroughly vet the identified R&D challenges against FAA R&D needs to produce a refined list of challenges, in which the priority of each challenge to the FAA and to the performing agencies is identified, as well as an indication of the amenability of each challenge to the R&D portfolios and capabilities of the R&D performers.

The next step will be to further vet the R&D challenges with the wider UAS community, including FFRDCs, manufacturers, universities and potential operators. This larger community will assist the committees in refining the challenge descriptions and identify additional contributing research being performed outside the portfolios of the partner agencies.

In addition to the three standing committees, ad hoc working groups will be formed to recommend detailed plans for addressing each R&D challenge. The composition of each ad hoc working group will be decided by the Technical Committee, drawing on appropriate subject matter experts. Working group members will possess expertise critical to the challenge area being addressed. These working groups will examine in detail all existing and planned agency programs that may contribute to addressing their R&D challenge area, and they will also consider and leverage non-agency programs. The working groups will perform activities such as the following for each challenge:

- Characterize the information and steps needed to address the challenge
- Identify and describe existing and planned programs addressing the challenge
- Assemble programs on a timeline, identifying on and off ramps and linkages among programs
- Identify key milestones and decision point on this timeline
- Identify gaps in which current planned programs are inadequate to fully address the challenge
- Formulate specific recommendations as to additional research needed or modifications to planned programs that will enable accomplishing critical milestones to address the challenge

The Technical Committee will receive, review, and organize the findings and recommendations of the ad hoc working groups into a detailed, coordinated plan of R&D across the partner agencies that will address the critical R&D challenges for successful integration of UAS operations in NextGen. The plan will address the needs of the airspace managers and regulators, as well as the needs of potential UAS operators in NextGen airspace, and it will reflect the points of view of all partner agency stakeholders

The execution of this research management plan is an ongoing process that will be carried out over the coming years until fully integrated UAS operations are enabled in the NextGen NAS. The overall effort is intended to produce an actively managed process, rather than a static document. The present UAS RD&D Roadmap, version 1.0, serves as the baseline for future efforts. Version 2 of the UAS RD&D Roadmap, to be completed by September 30, 2012, will reflect the vetted and prioritized challenges and interdependencies identified among performing agency R&D plans and programs to address the highest priority R&D challenges. Future versions of the Roadmap will be published as needed to reflect the evolution of this effort as multiagency R&D plans are executed, challenges are successfully addressed, and new challenges emerge.

Chapter Three

Performer-Identified UAS R&D Challenges

The task of identifying critical research challenges was approached by first dividing the domain into four categories of challenge areas chosen to allow groups of experts to most effectively work together in their related areas of expertise. These categories are common in discussion of UAS technology. The Communication category refers to communications among the aircraft, the operator, and satellite or other technology involved in relaying those communications. Airspace Operations deals with issues such as separation assurance and collision avoidance, as well as other issues arising from unmanned and manned vehicles sharing the same airspace. Unmanned Aircraft includes discussion of onboard systems pertaining to the aircraft itself. Human Systems Integration deals with the human in the loop of UAS operations, including the human pilot's interaction with and optimal design of the ground control station (GCS)[7] equipment interface, sources and mitigations for human error, and communications between the ground-based pilot and air traffic control.

Three technical working meetings were held in 2011, at which subject matter experts chosen by each partner agency met to develop consensus on the critical R&D challenges that they, as leading researchers in their respective areas of expertise, believe must be addressed in order to enable safe integration of UAS operations in the NextGen NAS. This chapter summarizes the outcomes of the workshops. The R&D challenges were identified, and a mapping was made of the partner-agency R&D programs addressing each challenge.

For each challenge, the subject matter experts identified which of the partner agencies are investing in research addressing that area, as well as major research programs addressing the area. Goals were identified that represent capabilities or knowledge that can be delivered by investment in R&D to address the challenge. Levels of coverage are also assessed for most challenges to determine whether current or planned R&D programs are sufficient to address all aspects of that R&D challenge.

Interim goals were identified for each challenge. It is important to note that these goals are based on the current five-year budgetary planning horizon. Planning for longer-term goals will first require developing integrated long-term plans for each of the challenges; that work will be addressed in 2012.

Detailed descriptions of the challenges are presented in this chapter and summarized in Appendix B. For each R&D challenge, the subject matter experts identified national goals, intended to provide baseline input to the ad hoc working groups that will meet in 2012. Figure 3, on the next page, plots the notional goals by challenge on a preliminary timeline, pending vetting and refinement by the ad hoc working groups.

---

[7] In accordance with current usage, this report refers to ground control stations. However, the control stations could also be aboard ships, vehicles, or other aircraft.

CHALLENGES	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030
1. Communications												
1.1 Impact of UAS Operations on NAS Communication Systems		Δ Goal 1 TBD				Δ Goal 2 TBD						
1.2 Ensure Availability of UAS Control Frequency Spectrum		Δ Goal 1 TBD				Δ Goal 2 TBD						
1.3 Develop and Validate UAS Control Communication System Performance Requirements				Δ Goals 1 & 2 TBD		Δ Goal 2 TBD						
1.4 Ensure Security of Safety Critical Communications with UAS		Δ Goal 1 TBD			Δ Goal 2 TBD							
1.5 Design and Develop UAS Control Datalink for Allocated UAS Frequency Spectrum Bands	Goals 1 & 2 TBD											
2. Airspace Operations												
2.1 Develop Integrated Separation Concepts		Δ Goals 1 & 2			Δ Goal 3							
2.2 Develop Airspace Integration Safety Case/Assessment		Δ Goals 1 & 2		Δ Goal 3 (2014+)								
2.3 Develop Sense and Avoid (SAA) Sensors and Fusion	Δ Goal 1	Δ Goal 2*	Δ Goal 2*									
2.4 Develop Separation Algorithms	Δ Goal 1	Δ Goal 2			Δ Goal 3							
2.5 Assess Availability/Quality of Surveillance Data		Δ Goals 1 & 2			Δ Goal 3			Δ Goal 4				
2.6 Develop Safe and Efficient Terminal Airspace/Surface Operations		Δ Goal 1		Δ Goal 2				Δ Goal 3				
3. Unmanned Aircraft												
3.1 State Awareness and Real-Time Mission Management				Δ Goal 1						Δ Goal 2		
3.2 Airframe Certification										Δ Goals 1 & 2		Δ Goal 3
3.3 Precise Location and Navigation	TBD											
3.4 UAS Avionics and Control Systems Certification								Δ Goal 1			Δ Goal 2	Δ Goal 3
4. Human Systems Integration												
4.1 Display of Traffic/Airspace Information							Δ Goal 1					
4.2 Effective Human-Automation Interaction				Δ Goal 1				Δ Goal 2				
4.3 Pilot-Centric GCS							Δ Goal 1					
4.4 Definition of Roles and Responsibilities							Δ Goal 1					
4.5 Predictability and Contingency Management							Δ Goal 1					
4.6 System-Level Issues							Δ Goal 1					
4.7 NextGen Airspace Users and Providers -- Qualification and Training						Δ Goal 1						
4.8 Support for Future/Enhance Capability of UAS				Δ Goal 1								

* Goal 2 (Challenge 2.3) is divided into two parts, each with a different timeframe.

Assessment of Level of Coverage Key:	
Coverage to be determined (TBD)	TBD (grey)
Strong or sufficient coverage	(green)
Fair coverage	(yellow)
Poor coverage or partial coverage	(orange)

Figure 3 Estimated levels of coverage of notional goals based on current UAS R&D portfolio

Performer-Identified UAS R&D Challenges by Category

1. Communications

1.1 Impact of UAS operations on NAS communication systems

Description of the challenge: Characterize the capacity and performance impact of UAS operations on Air Traffic Control (ATC) communications system. Identify the requirements and modifications needed to NextGen communications systems.
Assumptions: The current and planned ATC communications systems are not designed to account for the integration of UAS.
Major R&D investors: FAA, NASA, DHS
Major ongoing and planned R&D activities: UAS NextGen Demonstrations 3 and 4, FAA-NEO, NASA-UAS in the NAS project
Gaps: Inadequate traffic forecast models for UAS; no plans to modify NextGen communications systems for UAS
Anticipated goals and approximate dates:
Goal 1: The demonstration of an integrated terrestrial voice communications network that includes UAS Demonstration 4; 2012
Goal 2: Complete characterization of capacity and performance impact of UAS on ATC communications systems; 2016

1.2 Ensure availability of UAS control frequency spectrum

Description of the challenge: Civil UAS require protected safety frequency spectrum for control communications; no such spectrum allocations currently exist. Detailed technical analyses and compatibility studies are required to identify and obtain international allocations.
Assumptions: DOD will use its existing spectrum for control communications.
Major R&D investors: NASA, FAA, DOD, DHS
Major ongoing and planned R&D activities: NASA UAS in the NAS project, FAA Spectrum Office
Gaps: None
Anticipated goals and approximate dates:
Goal 1: Allocation of two terrestrial bands, by World Radio Communications (WRC) Conference, 2012
Goal 2: Allocation of satellite communications bands, by WRC Conference, 2016

1.3 Develop and validate UAS control communication system performance requirements

Description of the challenge:; Develop and validate detailed UAS control communications technical performance requirements based on communications policy and procedures, communications architectures, and safety considerations to be established.
Assumptions: There will be an initial set of policy, architecture and safety requirements; these will evolve. An iterative process is required to develop final communications technical performance requirements.
Major R&D investors: NASA, FAA
Major ongoing and planned R&D activities: UAS in the NAS project, FAA-ATO, FAA-AVS

Gaps: Policy, architecture selection, and safety and hazard analysis needs to be done sooner than currently planned.
Anticipated goals and approximate dates:
Goal 1: Complete large scale simulations of initial performance requirements, 2014
Goal 2: Complete flight testing of initial performance requirements, 2014
Goal 3: Verify and validate final performance requirements, 2016

1.4 Ensure security of safety-critical communications with UAS

Description of the challenge: Communications infrastructure between FAA, UAS operator and UAS needs to be secure. Develop and validate techniques and methods to ensure communications system security.
Assumptions: UAS systems require higher level of security than piloted systems.
Major R&D investors: NASA, FAA, DOD, DOT Volpe
Major ongoing and planned R&D activities: UAS in the NAS, FAA (Data Comm, NextGen Voice System)
Gaps: Potential gap on ATC links
Anticipated goals and approximate dates:
Goal 1: Vulnerability analysis of UAS safety critical communications, 2012
Goal 2: Develop and validate technologies to mitigate vulnerabilities, 2015

1.5 Design and develop UAS control datalink for allocated UAS frequency spectrum bands

Description of the challenge: Develop and validate hardware and standards for UAS control communications operating in allocated UAS spectrum.
Assumptions: UAS specific spectrum allocation is made at WRC 2012.
Major R&D investors: NASA
Major ongoing and planned R&D activities: NASA UAS in the NAS
Gaps: No known gaps
Anticipated goals and approximate dates
Goal 1: Develop and validate UAS control link prototype
Goal 2: Establish UAS control link national/international standards

2. Airspace Operations

2.1 Develop Integrated Separation Concepts

Description of the challenge: The unmanned aircraft Collision Avoidance (CA), Self-Separation (SS), and Separation Assurance (SA) functions overlap and interact and therefore need to be integrated in a systematic manner. This requires the evaluation of the performance of different functional allocations for SA/SS/CA, the evaluation of the performance of different human/machine roles and responsibilities, and the integration of the separation assurance, self-separation, and collision avoidance functions.
Assumptions: Surveillance data for SA will exist in the appropriate timeframe. Validated requirements for SA, SS and CA will be available in an appropriate timeframe.
Major R&D investors: FAA, NASA, DOD, DHS
Assessment of level of coverage: Current and planned activities, if executed, provide strong coverage.

Anticipated goals and approximate dates:
Goal 1: Develop pilot, ATC, and automation roles and responsibilities concepts, 2012
Goal 2: Develop integrated, autonomous and human-in-the-loop sense and avoid (SS & CA) algorithms, 2012
Goal 3: Develop integrated, autonomous and human-in-the-loop SA algorithms and integration with SS & CA, 2015
Notes: The roles and responsibilities evaluation in this challenge will be worked in conjunction with the Human Systems Integration Roles and Responsibilities challenge.

2.2 Develop Airspace Integration Safety Case/Assessment

Description of the challenge: Develop a rigorous, analytical methodology for substantiating the safety of UAS operations in the NAS. This requires understanding of the risks and failure modes of SA/SS/CA integration, the performance of human/machine roles and responsibilities and the integration of separation assurance, self-separation and collision avoidance functions.
Assumptions: System, subsystem, and component-level technologies are understood and documented sufficiently to support safety case development.
Major R&D investors: FAA, NASA, DOD
Assessment of level of coverage: Current and planned activities, if executed, provide strong coverage.
Anticipated goals and approximate dates:
Goal 1: Develop safety case methodology through analysis and specific assessments, 2012
Goal 2: Develop Target Level of Safety criteria for UAS Airspace Operations, 2012
Goal 3: Provide performance data and analyses to support safety case development, 2014+
Notes:

1. A complete safety case would cover much more than just the airspace operations components.
2. Providing supporting data and analyses is an ongoing process—output from most technology development activities
3. Gap: The "official" airspace model against which UAS will be evaluated does not exist. That might need to be captured as an activity or set of activities here.
4. The roles and responsibilities evaluation in this challenge will be worked in conjunction with the Human Systems Integration Roles and Responsibilities challenge.
5. Various NextGen technologies, including Cockpit Display of Traffic Information, will be explored and a safety case analysis will be conducted.

2.3 Develop Sense and Avoid Sensors and Fusion

Description of the challenge: Safe operation will likely be achieved through data obtained from a variety of sources, including onboard, offboard and cooperative sensors. Developing and evaluating sensors and sensor data fusion algorithms and approaches will be key to achieving the integrity required.
Assumptions: Validated requirements for SS and CA will be available in an appropriate timeframe.
Major R&D investors: FAA, DOD, DHS
Assessment of level of coverage: Current and planned activities, if executed, provide strong coverage.

Anticipated goals and approximate dates:
Goal 1: Demonstrate mosaic of primary and secondary radars on CDTI display; 2011
Goal 2: Flight demonstrate fusion of EO/IR, radar, TCAS and Automatic Dependent Surveillance-Broadcast (ADS-B); 2012; SWIR/radar; 2013

2.4 Develop Separation Algorithms

Description of the challenge: As the key to safe, efficient and "expected" behavior in the airspace, the maneuvering algorithms are a critical component of airspace operations. Therefore, Separation Assurance, Self-Separation, and Collision Avoidance algorithms must be developed to minimize impact to operations while maintaining safety. These algorithms and the analyses will inform many policy decisions (algorithm-based or requirements-based standards). While avoiding other aircraft is the critical function, future safety concerns will include weather, wake vortices, terrain, etc.
Assumptions: Validated requirements for SA, SS and CA will be available in an appropriate timeframe.
Major R&D investors: FAA, DOD, NASA
Assessment of level of coverage: Current and planned activities, if executed, provide strong coverage.
Gap: The "official" airspace model against which separation algorithms will be evaluated does not exist.
Anticipated goals and approximate dates:
Goal 1: Flight demonstrate SS & CA algorithms, multiple sensors and intruders, 2011
Goal 2: Evaluate risk-based SS algorithm and policy issues, 2012
Goal 3: Flight demonstrate SA algorithms, criteria-based separation, 2015

2.5 Assess Availability/Quality of Surveillance Data

Description of the challenge: NextGen aircraft will have a variety of available surveillance data sources and performance of the separation algorithms depends on the quality of the data. Different levels of data availability/reliability/integrity/continuity/ accuracy (air vs. ground, weather, ATC vs. other users) must be assessed. The availability and impact of intent/trajectory prediction information on operations performance must also be assessed. While knowledge of other aircraft is the critical item, future concerns will include weather, wake vortices, etc.
Major R&D investors: FAA, DOD, NASA
Assessment of level of coverage: Current and planned activities, if executed, provide strong coverage.
Anticipated goals and approximate dates:
Goal 1: Establish surveillance data concepts, separation volume definition and roles and responsibilities, 2012
Goal 2: Assess performance of various self-separation concepts as a function of surveillance data configurations, 2012
Goal 3: Assess performance of various separation assurance concepts as a function of surveillance data configurations, 2015
Goal 4: Assess benefits of availability of intent information, 2018

2.6 Develop Safe and Efficient Terminal Airspace/Surface Operations

Description of the challenge: Complete airspace operations include operations in a terminal/surface environment where efficiency as well as safety is paramount. Operations in this complex and restrictive environment create additional challenges in guidance and navigation, integrity management, responsiveness to ATC commands, sensors and collision avoidance.

Major R&D investors: FAA, DOD, NASA

Assessment of level of coverage: Current and planned activities, if executed, provide strong coverage.

Anticipated goals and approximate dates:

Goal 1: Evaluate impact of multiple UAS in terminal airspace controller workload, 2012

Goal 2: Evaluate surveillance data sources in terminal environment, 2014

Goal 3: Ground demonstration of autonomous airfield navigation and ATC interaction, 2018

3. Unmanned Aircraft

3.1 State Awareness and Real Time Mission Management

Description of the challenge: UAS often change trajectories many times during flight, negotiating these changes on a real-time basis is labor intensive and inefficient. Furthermore, without a pilot on board, the UAS will have to generate awareness of the aircraft state during operations. Research in this area provides aircraft systems state awareness and thereby enable efficient and timely trajectory negotiations at multiple levels, e.g., aircraft, system-of-systems and NAS levels. The technology could also be critical for certifying aircraft safety in the event of component failures for operations in the NAS.

Assumptions: In general a common architecture needs to be developed to allow for technology development. This architecture is more than just aircraft it includes ground system. We assume that a standard functional architecture will be developed for NextGen.

Major R&D investors: DOD-Air Force/Navy, NASA

Assessment of level of coverage: Current and planned activities, if executed, provide fair coverage.

Anticipated goals and approximate dates:

Goal 1: Demonstrate real-time state awareness for unmanned space access, 2014

Goal 2: Demonstrate real-time trajectory negotiation based on state awareness in NAS, 2020

3.2 Airframe Certification

Description of the challenge: Enable the rapid and affordable airframe certification for all types of UAS through increase emphasis on structural analysis and reduction in airframe testing. The existing basis of certification does not cover the new and novel materials and manufacturing processes being used in the manufacturing of UAS. As these methods and materials continue to evolve, research is needed to support an airworthiness determination and continue to ensure airworthiness over the life of the aircraft.

Assumptions:

Major R&D investors: DOD-Air Force

Assessment of level of coverage: Current and planned activities, if executed, provide poor coverage.

Goals:
Goal 1: Certify an airframe by analysis verified by test, 2020
Goal 2: Develop certification standards for advanced materials and structural design, 2020
Goal 3: Continued airworthiness through onboard health monitoring, 2030

3.3 Precise Location and Navigation

Description of the challenge: UAS are being developed with a strong dependence on GPS as a source for Guidance, Navigation, and Control information, so much so that a single failure mode situation is potentially present. Without a human pilot on board to provide a means of back-up, critical situation awareness would be lost, and the platform could put human life and infrastructure at risk.
Major R&D investors: DOD-Air Force
Note: Much of this research is not publicly releasable and is therefore not discussed in this document.

3.4 UAS Avionics and Control Systems Certification

Description of the challenge: Existing software verification and validation tools and techniques are inadequate to address the complexity of emerging avionics and control software suites. As such, new tools and techniques are necessary to support UAS development to ensure the safety and reliability of these systems.
Major R&D investors: DOD-Air Force, NASA
Assessment of level of coverage: Current and planned activities, if executed, provide poor coverage
Anticipated goals and approximate dates:
Goal 1: Demonstrate software certification artifacts using analysis and reduce testing, 2018
Goal 2: Demonstrate methodology for System of Systems interaction modeling and certification, 2025
Goal 3: Develop methodology for shared redundancy certification, 2030

4. Human Systems Integration

4.1 Display of Traffic/Airspace Information

Description of the challenge: Develop display of traffic/airspace information. This information would include traffic information (knowledge of equipage); airspace information (weather, etc.); separation assurance interface (sense and avoid); visualization tools (weather, wind, traffic, air routes, frequency); and displays/tools for enable and monitoring of Ground Control Station (GCS) NextGen trajectory- based operations for dynamic re-planning.
Assumptions: No additional assumptions
R&D investors: NASA, DOD-Air Force, FAA
Assessment of level of coverage: Current and planned activities, if executed, will partially address this challenge.
Goals:
Goal 1: Integrate NextGen-representative technologies for traffic, weather, and terrain avoidance into a GCS, 2017.

4.2 Effective Human-Automation Interaction

Description of the challenge: Provide needed data to enable effective human-automation interaction for UAS in the NAS. Issues of concern within this area include automation implementation (trust, predictability, understanding, control loops—manned vs. unmanned); levels of automation (mode awareness, transparency, bias/trust); and human-automation interface (SA, vigilance decrements, skill degradation).

R&D investors: NASA, DOD-Air Force

Assessment of level of coverage: Current and planned activities, if executed, are sufficient to address this challenge.

Goals:

Goal 1: Define task allocation for human automation for all phases of flight, 2014.

Goal 2: Define appropriate levels of automation, transparency, maintained operator engagement and flexible, intuitive control, 2018.

4.3 Pilot-Centric GCS

Description of the challenge: Prototype and empirically validate pilot-centric GCS operator interface. Sub-issues within this challenge include minimum equipment list (display, controls, etc.); identify and reconcile the delta between manned and unmanned; sensory deficit and remediation; address communication latency in design; handoffs (within a single GCS and between GCS); and configuration/facility (sterile cockpit).

R&D investors: NASA, DOD-Air Force, FAA

Assessment of level of coverage: Current and planned activities, if executed, are sufficient to address this challenge.

Goals:

Goal 1: Demonstrate GCS that meets requirements to safely operate a specific UAS in the NAS at acceptable pilot workload levels, 2017.

4.4 Definition of Roles and Responsibilities

Description of the challenge: Understand and design for NextGen roles and responsibilities. Sub-issues within this challenge include changing roles and responsibilities for NextGen communication flow among UAS team, ATC, and flight dispatchers; function allocation (operators, ATC, automation, human); and roles and responsibilities for mission management in contingencies; and centralized/distributed decision making. This challenge is directly related to Airspace Operations challenges (Develop Integrated Separation Concepts) and the section on Develop Airspace Integration Safety Case/Assessment.

R&D investors: NASA, DOD-Air Force

Assessment of level of coverage: Current and planned activities, if executed, will partially address this challenge.

Goals:

Goal 1: Inform and demonstrate the feasibility and acceptability of NextGen roles and responsibilities, 2017.

4.5 Predictability and Contingency Management

Description of the challenge: Integrate effective contingency management system with GCS. Sub-issues within this challenge area include: recognition of new system faults and proper response in NextGen; identifying appropriate predictability requirements (aircraft, ATC, pilots of manned aircraft); lost/intermittent link status/health; and lost communications to ATC.

R&D investors: NASA, DOD-Air Force

Assessment of level of coverage: Current and planned activities, if executed, will partially address this challenge.

Goals:

Goal 1: Develop an integrated Caution Warning Advisory for normal and contingency operations, 2017.

4.6 System-Level Issues

Description of the challenge: Understand human system integration (HIS) aspects of system-level analyses of UAS/NextGen environment. Sub-issues within this challenge include NAS-wide human- performance requirements with toolset of test-bed and metrics; information requirements and flow among UAS, ATC; and ATC compliance equivalency (crew and overall system response).

R&D investors: None

Assessment of level of coverage: Current and planned activities, if executed, provide poor coverage of the research challenge.

Goals:

Goal 1: Determine where the human component exists within the system architecture (mission task analysis) and inform the definition of roles and responsibilities for all components of the system. In addition identify performance requirements and information requirements, 2017.

4.7 NextGen Airspace Users and Providers – Qualification and Training

Description of the challenge: Formulate NextGen-specific qualification and training requirements for users and providers. Sub-issues within this challenge area include crew/ATC skill set; training, certification; and qualification.

R&D investors: DOD-Air Force

Assessment of level of coverage: Current and planned activities, if executed, will partially address this challenge.

Goals:

Goal 1: Inform minimum set of standards for all users and providers regarding operation in the NAS, 2016.

4.8 Support for Future/Enhance Capability of UAS

Description of the challenge: Support future and enhanced capability for UAS. Sub-issues within this challenge area include net-centric operations, cooperative control/swarming, and multiple UAS control by a single control system.

R&D investors: DOD-Air Force

Assessment of level of coverage: Current and planned activities, if executed, are sufficient to address this challenge.

Goal:

Goal 1: Demonstrate increasing multiple aircraft control capability for benign operations (transit) by a single operator, 2014.

Path to Refinement of UAS R&D Challenges

As each agency has a unique mission and portfolio, coordinating R&D across agencies will require that for each R&D challenge, the importance of that challenge to each agency must be identified, as well as the ability of each agency to address that challenge within its portfolio. This chapter lists critical R&D needs as identified by the R&D performers within each agency. In addition, the FAA has described (see Appendix A) the information they need from R&D performers in order to enable fully integrated UAS operations in the NextGen NAS.

The first task of the Technical Committee in 2012 will be to thoroughly vet the identified R&D challenges against FAA R&D needs to produce a refined list of challenges, in which the priority of each challenge to the FAA is identified, as well as an indication of the amenability of each challenge to the R&D portfolios and capabilities of the R&D performers.

Table II on the next page represents an initial analysis aligning the FAA's R&D needs identified in Appendix A (Partner Agency Perspectives) with the performer-identified R&D challenges. This notional comparison may be used as a baseline for the process of reconciling R&D challenges from the performer and user perspectives.

After intra-agency vetting is complete, the next step will be to further vet the R&D challenges with the wider UAS community including FFRDCs, manufacturers, universities, and potential operators. This larger community will assist the committees in refining the challenge descriptions and help to identify additional contributing research being performed outside the portfolios of the partner agencies.

Table II Initial Analysis of FAA R&D Needs Addressed by Identified Critical R&D Challenges

R&D Challenges	FAA Needs						
	Develop and validate UAS performance requirements for normal and abnormal operations	Resolve UAS and ATC interoperability issues during normal and abnormal operations	Provide robust failure modes and recovery operations	Validate NextGen concepts (e.g., "4D trajectory based") using UAS as testbed.	Develop adequate safety case of UAS NAS integration	Develop required policies, standards and certification guidance material	Develop concepts for the wide-spread integration of UAS into the future NAS
1. Communications							
1.1 Impact of UAS operations on NextGen communication systems	X	X			X		
1.2 Ensure availability of UAS control frequency spectrum					X	X	
1.3 Develop and validate UAS control communication system performance requirements	X				X		
1.4 Ensure security of safety critical communications with civil UAS	X	X	X		X	X	
1.5 Design and develop UAS control datalink for allocated UAS frequency spectrum bands	X		X		X	X	
2. Airspace Operations							
2.1 Develop Integrated Separation Concepts	X	X	X		X		X
2.2 Develop Airspace Integration Safety Case/Assessment					X		
2.3 Develop Sense and Avoid (SAA) Sensors and Fusion	X	X	X		X		
2.4 Develop Separation Algorithms	X				X		
2.5 Assess Availability/Quality of Surveillance Data	X		X		X	X	
2.6 Develop Safe and Efficient Terminal Airspace/Surface Operations	X	X	X		X		X
3. Unmanned Aircraft							
3.1 State Awareness and Real Time Mission Management	X	X	X		X	X	
3.2 Airframe Certification			X		X	X	
3.3 Precise Location and Navigation	X				X		
3.4 UAS Avionics and Control Systems Certification	X		X		X	X	
4. Human Systems Integration							
4.1 Display of Traffic/Airspace Information	X			X	X	X	X
4,2 Effective Human-Automation Interaction	X	X	X	X	X	X	X
4.3 Pilot-Centric GCS	X			X	X	X	X
4.4 Definition of Roles and Responsibilities	X	X			X		X
4.5 Predictability and Contingency Management	X	X	X		X		
4.6 System-Level Issues		X			X		X
4.7 NextGen Airspace Users and Providers – Qualification and Training					X	X	
4.8 Support for Future/ Enhance Capability of UAS					X		X

Chapter Four

Demonstrations and Collaboration

Coordination and cooperation among the research performers of the partner agencies is not new. There are a number of success stories in UAS research across agency; a few are listed below. In addition, in order to highlight the potential for joint demonstrations, participants in the working meetings identified two particularly promising opportunities for joint demonstrations, in which the participation of multiple partners would yield significant benefits.

Successful Ongoing Collaborations

UAS in the NAS
As part of the UAS Integration in the NAS project, NASA plans to develop concepts of operations that include development of SA technology and integration of existing CA and SS algorithms to investigate their performance and interoperability under different traffic and airspace conditions.

As part of an ongoing collaboration between NASA and AFRL, NASA is planning to integrate the Jointly Optimal Conflict Avoidance (JOCA) algorithms and software into the simulation platform being developed to support both human in the loop (HITL) and fast time experiments.

Operational Procedures
FAA and DOD joint demonstration with multiple UAS in airspace

Verification and Validation of Complex Software Systems
NASA and Air Force and the NSF effort (CPS)

Sense and Avoid
USAF and FAA joint flight test/demonstration of SAA system

FAA and DOD joint demonstration of GBSAA concept at Cherry Point

Ground Collision Avoidance System
USAF and NASA joint flight test/demonstration of Auto-GCAS system

Networking and Information Technology R&D (NITRD) National Coordination Office Cyber Physical Systems Consortium
As part of an interagency effort, the National Coordination Office for NITRD, NASA, DOD, FDA, NRC, and JPDO are collaborating on automation and robotics. Specifically, the agencies are coordinating research in software/system certification. This group is leveraging funded research at each of the agencies. Furthermore, a transportation R&D-needs OSTP report is being produced this year that highlights some of the needs in this report.

NASA – Air Force Executive Research Committee
This body meets to explore collaborative opportunities.

NATO HFM-170 Working Group on Supervisory Control of Multiple Uninhabited Systems: Methodologies and Enabling Human-Robot Interface Technologies
The purpose of this working group is to identify and demonstrate successful supervisory control methodologies and interface design practices for enabled single operator control of multiple unmanned vehicles with varying degrees of autonomy. The working group was composed of nine countries and 18 participants. Unlike other NATO HFM groups, this one focused on technology demonstrations of varying technology readiness levels (TRLs). The group will feature a technology forum in the final year (2012) of their collaboration.

U.S. – Israel Project Agreement on Rotorcraft Aeromechanics and Man-Machine Integration Technologies
The RICH task (rapid immersion tools and techniques) focuses specifically on developing tools and techniques to support quick situation awareness building for effective collaboration and mission execution. The ability to rapidly come up to speed will be required to support future concepts of operations in multi-operator, multi-UAS (MOMU) environments. Collaborators on the task include researchers from the U.S. Army, the U.S. Air Force, the Israeli Ministry of Defense, Ben Gurion University of the Negev, and Synergy LTD.

Proposed Joint Agency Collaborations

Human-Centered Integrated Ground Station Solution
Description: Any information presentation solution to provide required NAS information will be a significantly better design and impose lower workload if it is part of an overall integrated human centered design.
Relevant Programs:
1. NASA – UAS in the NAS: In keeping with the spirit and intent of NASA's ISRP, the UAS in the NAS program is focusing on defining the required information and developing displays for proof of concept of a complete integrated solution. As a result of several factors, not the least of which is the proprietary nature of most fielded GCS, this project does not intend to focus on an overall integrated GCS solution. This effort differs from the FAA's efforts, where programs are focused on analytically defining the minimum acceptable level of information.
2. AFRL – Vigilant Spirit Control Station (VSCS): AFRL's Vigilant Spirit program is a software application that provides an advanced operator control/display interface enabling single- and multi-UAV control across diverse missions. It contains numerous innovative and intuitive graphical user interface components, utilizes automation aids to assist with flight control, route generation and sensor management, and directly supports human centered simulations and UAV flight tests. VSCS instantiates a flexible, government owned software architecture with a strong focus interoperability and user interface commonality by integrating non-proprietary standards whenever possible such as NATO STANAG 4586 and H-264 encoded digital video.

Proposed Effort: The proposed collaboration will build on the information requirements developed by the NASA UAS in the NAS program to jointly develop an overall human-centered operator display design solution for the presentation of airspace, traffic, and other information critical to routine UAS operation in the NextGen NAS. These information displays will be instantiated and integrated into the Vigilant Spirit Control Station (VSCS) in a user-centered manner. VSCS would then serve as the proof of concept ground control station for UAS in the NAS part- and full-task simulations and flight tests. During these events, usability assessments will take place that will motivate any needed design refinements to the airspace information displays.

Milestones:

- Information requirements definition (NASA)
- Candidate NAS-relevant information displays designed (NASA/AFRL)
- NAS-relevant information displays instantiated within VSCS (AFRL)
- Simulation and flight tests of VSCS with usability assessments (NASA/AFRL)

Deliverable: A flight-tested integrated human-centered GCS solution for UAS in the NAS.
Status: Technical discussions have taken place and a tentative timeline has been proposed.

FAA UAS NextGen Demonstrations

Description: Evaluate a UAS Surrogate Network (NAS Voice Switch/NVS), which will consist of:

- Restored GCS-ATC communications via NextGen NVS communications (Private Voice Over Internet Protocol [VOIP] connected to Digitally Networked Radio System [DNRS] network)
- NextGen ADS-B data (via the SWIM network or a simulated SWIM network).

There has also been discussion of evaluating the big-picture/traffic situation awareness of UAS pilots when they are given traffic displays. Demonstration 3 results suggested that, to be useful, these types of displays will need to be integrated with existing GCS displays, made consistent with existing aviation system displays, and tailored to support or be more consistent with UAS pilot work activities. This demonstration is in active planning and is expected to evolve prior to execution.

Relevant Programs:

1. FAA UAS NextGen Demonstrations
2. NASA – UAS in the NAS*:* NASA's UAS in the NAS program is focusing on defining the required information and developing displays for proof of concept of a complete integrated solution.
3. AFRL – Supervisory Control of UAS
4. DHS CBP-OAM provides UAS test bed to conduct FAA surveillance and communication studies at Cape Canaveral Air Force Station

Proposed Effort: FAA will perform and lead a flight demonstration to help ensure safe, organized flow of air traffic with UAS in the NAS.

Milestones:

September 2011, Kick-off
March 2012, Flight Demo

Deliverable: Empirical evaluation of big-picture/traffic situation awareness of UAS pilots when they are given traffic displays and ATC communications networked via a NextGen terrestrial network.

Status: Biweekly FAA telecoms have been joined by NASA and soon by USAF to help with providing resources for the flight demo.

As the agencies proceed in implementing the research management plan described in this document, additional opportunities for collaboration will be identified, and the development of joint demonstrations will emerge as part of the process of planning for the research of multiple agencies to converge toward the delivery of identified, high priority R&D products.

Chapter Five

Conclusions and Next Steps

In response to a request by OMB, the NextGen partner agencies have accelerated a process begun in 2010 of more closely coordinating research intended to enable full UAS integration in the NextGen airspace. Initially an informal effort among the FAA, NASA and the AFRL, the effort now encompasses DOC and DHS, with full engagement by all DOD services under the auspices of the Office of the Undersecretary of Defense for Acquisition, Technology and Logistics.

Ultimately, this effort will produce detailed plans across agencies of specific R&D programs addressing each critical R&D challenge. Under this plan, agencies will perform the work best suited to their portfolio and capabilities and that falls within their purview and budgetary constraints. Partner agencies will share the knowledge acquired in these leveraged programs to enable rapid progress by research partners in their parallel efforts. The agencies will engage in joint demonstrations at critical junctures where such demonstrations would prove cost effective and enable more rapid progress. These lines of research will be planned and overseen using the management structure described in Chapter 2 and diagrammed in Figure 2. The FAA and other NextGen partner agencies' leadership will remain fully engaged in the research management process through the NextGen UAS R&D Executive Committee and the NextGen UAS R&D Committee Planning Committee. They provide direction to the NextGen UAS R&D Technical Committee, who ensure that critical technology and information needs are communicated clearly across the partner agencies to satisfy FAA requirements for UAS integration into the NextGen NAS.

To date, the partner agencies have accomplished the following steps:

- The Roadmap process has secured commitments from leadership within the partner agencies for resources and subject matter experts to identify critical UAS technical challenges and create the NextGen UAS RD&D Roadmap
- The multiagency workshops have produced a consensus across R&D performers in the NextGen partner agencies as to a critical preliminary set of UAS R&D challenges to be addressed
- The FAA has developed and contributed a summary of FAA's UAS R&D needs
- All NextGen partners have contributed their agency R&D perspectives to facilitate cross-agency communication and identification of common areas of interest

As we move forward, the development of critical UAS research activities will continued to be coordinated and integrated across all levels of participation, including executive oversight, management planning, and technical execution. Evolving the information contained in this document into detailed program-level plans to achieve specific R&D challenges will require fully vetting the challenges with the NextGen partner agencies and with the larger community involved with UAS to meet the following objectives:

- Ensuring that these challenges comprise a complete and necessary set

- Ensuring that the challenges are described and prioritized in a way that makes the likely outcome most useful to the end users, including the FAA
- Identifying related work being conducted outside the partner agencies' portfolios (for example, FFRDCs, universities, and private companies)
- More fully describing the status and gaps associated with each challenge
- Clarifying incremental goals and expected products and timelines to be delivered for each challenge

The first step in this vetting process will be to crosslink the performer-identified R&D challenges with FAA R&D needs to produce a refined list of challenges, in which the priority of each challenge to the FAA is identified, as well as an indication of the amenability of each challenge to the R&D portfolios and capabilities of the R&D performers. The next step in the vetting process will enlist the wider UAS community including FFRDCs, manufacturers, universities and potential operators. This larger community will assist the committees in refining the challenge descriptions and identify additional contributing research being performed outside the portfolios of the partner agencies

Once the R&D challenges have been fully vetted, the next phases of planning will tackle the highest priority challenges first. The NextGen UAS R&D Technical Committee will form ad hoc working groups composed of subject matter experts, including representatives of the partner agencies as well as non-agency experts as appropriate. These working groups will examine ongoing and planned R&D efforts and other relevant sources of information from stakeholders, including partner agencies and other government and nongovernment entities, in order to identify programs that may be leveraged together to more efficiently address each high priority challenge.

A fully integrated plan of research programs will be developed based on this information and recommended to decision makers. This plan will leverage already funded work in the partner agency portfolios as well as outside efforts. When the planned work is performed in close coordination with maximum sharing of information, and planned demonstrations where appropriate, it will allow the R&D challenges to be addressed in the most timely and cost-effective manner possible. The full participation of the FAA and other NextGen partner agencies in the formulation of these plans will ensure that the FAA receives the results in a form that is most useful to expedite decision making processes.

The execution of this research management plan is an ongoing process that will be carried out over the coming years until fully integrated UAS operations are enabled in the NextGen NAS. The overall effort described in this Roadmap is intended to produce an actively managed process, rather than a static document. The present NextGen UAS RD&D Roadmap, version 1.0, serves as the baseline for future efforts. Version 2 of the NextGen UAS RD&D Roadmap, to be completed by September 30, 2012, will reflect the vetted and prioritized challenges and interdependencies identified among performing agency R&D plans and programs to address the highest priority R&D challenges. Future versions of the Roadmap will be published as needed to reflect the evolution of this effort as multiagency R&D plans are executed, challenges are successfully addressed, and new challenges emerge.

Appendix A

Partner Agency Perspectives on UAS R&D

Federal Aviation Administration (FAA)

UAS R&D Perspectives for the Future NAS Environment

History of Involvement with UAS
Since the early 1990s, the FAA has been accommodating Unmanned Aircraft System (UAS) in the National Airspace System (NAS). In recent years, the number of requests to fly UAS operations in the NAS has risen significantly, with public operations alone increasing by over 900% since 2004. The unique capabilities and significant benefits that UAS are capable of delivering contribute to an increased operational demand by public and civil operators. To address this demand, the FAA adapted regulatory processes to provide avenues of NAS access for both public and civil operations without compromising the safety or efficiency of the NAS. Currently, public UAS operations conducted outside of active Restricted and Warning Areas are authorized under an FAA Certificate of Waiver or Authorization (COA). Civil UAS operations are approved through the FAA's Special Airworthiness Certificate - Experimental Category (SAC-EC) process that allows controlled access to the NAS for UAS research and development (R&D) as well as other special purposes. Since the first of these approvals in 2005, more than 90 SAC-EC's have been issued.

FAA's Role
The FAA is responsible for developing policy, regulatory guidance material, and standards for the existing NAS as well as any future airspace transformations. This responsibility includes the UAS civil certification basis and operational procedures development to ensure the safe integration of UAS into the NAS. While existing safety and aviation standards address manned aircraft, unmanned aircraft have demonstrated challenges in complying with some of these standards. In some cases (e.g., datalink), the appropriate standards do not exist. Metrics to measure UAS performance relative to manned aircraft flight in the NAS have not yet been established.

Research Challenges, Objectives, and Needs
The FAA is considering the operations of UAS in the NAS from three perspectives:

Perspective 1 – *Accommodation* – Ability to take today's UAS and apply special methods and procedures to safely facilitate limited access to the NAS. UAS operations in the NAS are considered on a case-by-case basis. During this period, R&D continues to identify challenges and validate mitigation strategies and explore opportunities to make progress toward UAS integration in the NAS.

Perspective 2 – *Transformation* – Establishing a threshold for performance requirements which existing and new UAS (i.e., block upgrade) can meet to provide increased access in the NAS. During this period, R&D continues and the agency will establish policy, regulations, procedures, and understanding of systems and operations to support routine NAS operations.

Perspective 3 – *Integration* – All required policy, regulations, procedures, technologies, and training are in place to support routine UAS operations in the NAS operational environment.

Transitioning from "Accommodation" to "Integration" will require a focus on specific research to support products and decisions along the path. The development of standards, certification approaches, policies, procedures and Air Traffic Control (ATC) system upgrades to support mixed-use operation of manned and unmanned aircraft while maintaining safety and efficiency of the NAS presents a challenge. Critical, structured, and properly vetted research is needed to address the numerous challenges. The following overview highlights focus areas that the FAA sees as necessary to achieve the objectives of these perspectives.

Accommodation

Today, there are many user needs for UAS access to the NAS in support of organizational operational objectives. These needs vary greatly depending on operation, system, and location. While consideration and planning for full UAS integration into the NAS continues, accommodation is currently the means to achieve access to the NAS while maintaining or improving today's level of safety and efficiency. Accommodation will remain an acceptable path in the future, but it is expected to be used less frequently.

Research in this phase is focused on evaluating risk mitigation strategies for operational procedures and the introduction of new technologies. This focus is specifically designed to safely support expanded, but controlled, access to the NAS for UAS operations. Today's unmanned aircraft fly in the NAS with specific mitigations that limit risk to the public. Identified risks are derived from limitations in today's systems, which include:

- Lack of certification to standardized requirements and procedures
- Performance measures that are not well known
- Unique functions that are not yet fully understood

Today's operations have two main modes, normal and contingency. Normal operations typically include:

- Spirals – climb to, and descent from, Class A airspace operations
- Orbits with or without changes in altitude
- Point-to-point flights
- Long duration flights
- Flight paths with extensive trajectory changes
- Flight operations in Class C, D, E, and G airspace over non-populated areas

Failed and degraded mode (contingency) operations typically include:

- Undetected failures resulting in an undetected loss of function
- Loss of command and control link
- Inability to coordinate with other NAS users and the air traffic service provider

- Inability to affect flight trajectory

Other activity considered in the accommodation of UAS includes research to support safety-case validation and the associated mitigations. This includes case-by-case assessments to determine the likelihood that a system or operation can achieve an acceptable safety level. The research will consider UAS operational and technical risks, including:

- Ability to maintain safe separation
- Ability to avoid a collision
- Ability to maintain positive control of the unmanned aircraft
- Ability to meet operational environment's expected behavior
- Ability to safeguard the public

Results of this research will aid in defining primary risk mitigations required due to inherent UAS limitations—notably no see-and-avoid capability—and secondary mitigations required due to UAS unique operational profiles and aircraft characteristics. Some examples are:

- Limiting exposure time
- Limiting exposure area
- Interoperability of controller decision-support tools
- Integrating independent functionality
- Informing and educating UAS users and the public
- Informing updates to controller procedures and training

Transformation

Although special airworthiness certificates and COAs will remain an avenue for accessing the NAS, emphasis will shift toward developing civil standards for UAS certification. This includes policy guidance and operational procedures required to enable manned and unmanned aircraft to fly together without degrading safety or the efficiency of the NAS. Transformation, by design, considers the current state of the NAS, as well new technologies and procedures. Transformation will continue to evolve as the NAS evolves.

Research is needed to help define UAS certification requirements. Appropriate research will guide the equipment design and technology development necessary to receive civil certification under existing or expanded regulations, guidance, and standards.

While current regulations, guidance, and standards assure safe operation of aircraft with pilots in the cockpit, these may not represent the necessary and sufficient basis for the design and operation of UAS. The transformation process will include the development of operational concepts, formulation of standards, and development of technologies that will be needed to enable manned and unmanned aircraft to operate in the same airspace. Efforts will focus on sequentially evolving the UAS system requirements established by the FAA, as follows:

- Develop an integrated set of FAA policy, operational guidance, procedures, and standards for civil aircraft airworthiness
- Define continued airworthiness methodologies
- Complete training and certification standardization

- Continue the technology development and assessment work that underpins the ability of UAS to operate safely and efficiently in the NAS

The approach to undertaking this exploration of UAS is to first examine manned vs. unmanned aircraft from the perspective of flight in the NAS. The following are key considerations:

Performance measures for normal operations

- Verbal and physical response time to ATC clearances and instructions
    - Acceptable speeds, climb, turn rates, and verbal response times are not quantitatively established
    - Human performance measures are not quantified

Performance measures for failed and degraded mode operations

- System failure characteristics
- Lost command and control link
- Degraded performance

Impact on the NAS

- Ability to comply with ATC instructions; e.g., maintain visual separation, follow an aircraft, or give way to another aircraft or vehicle when on the ground
- Ability to initiate a turn to a specific heading, level at an interim altitude, make a specific speed adjustment, hold as published, or execute and expect further clearance
- Ability to comply with unique requests—expedite a climb, execute a go-around
- Ability to see and avoid

Ability to perform in an expected and predictable manner

Performance Gap Analysis between Pilot and Avionics

Key research questions that need to be addressed regarding the lack of quantified pilot performance measures for any given airspace and the need to assign values for the design and construct of avionics systems include:

- What is baseline performance?
- What are the required performance measures/metrics?
- What are the regulatory gaps and associated research requirements?
- What are the technology gaps and associated research requirements?

Results of this research will assist the FAA in the appropriate consideration of UAS. Many products (see Figures A-1 and A-2) will need to be reviewed and considered for updating to specifically address UAS integration into the NAS. In some cases, new products, procedures, and training will need to be created. Each of these will require supporting rationale and data to validate assumptions and positions taken.

Figures A-1 and A-2 illustrate product areas relating to UAS that will require supporting research.

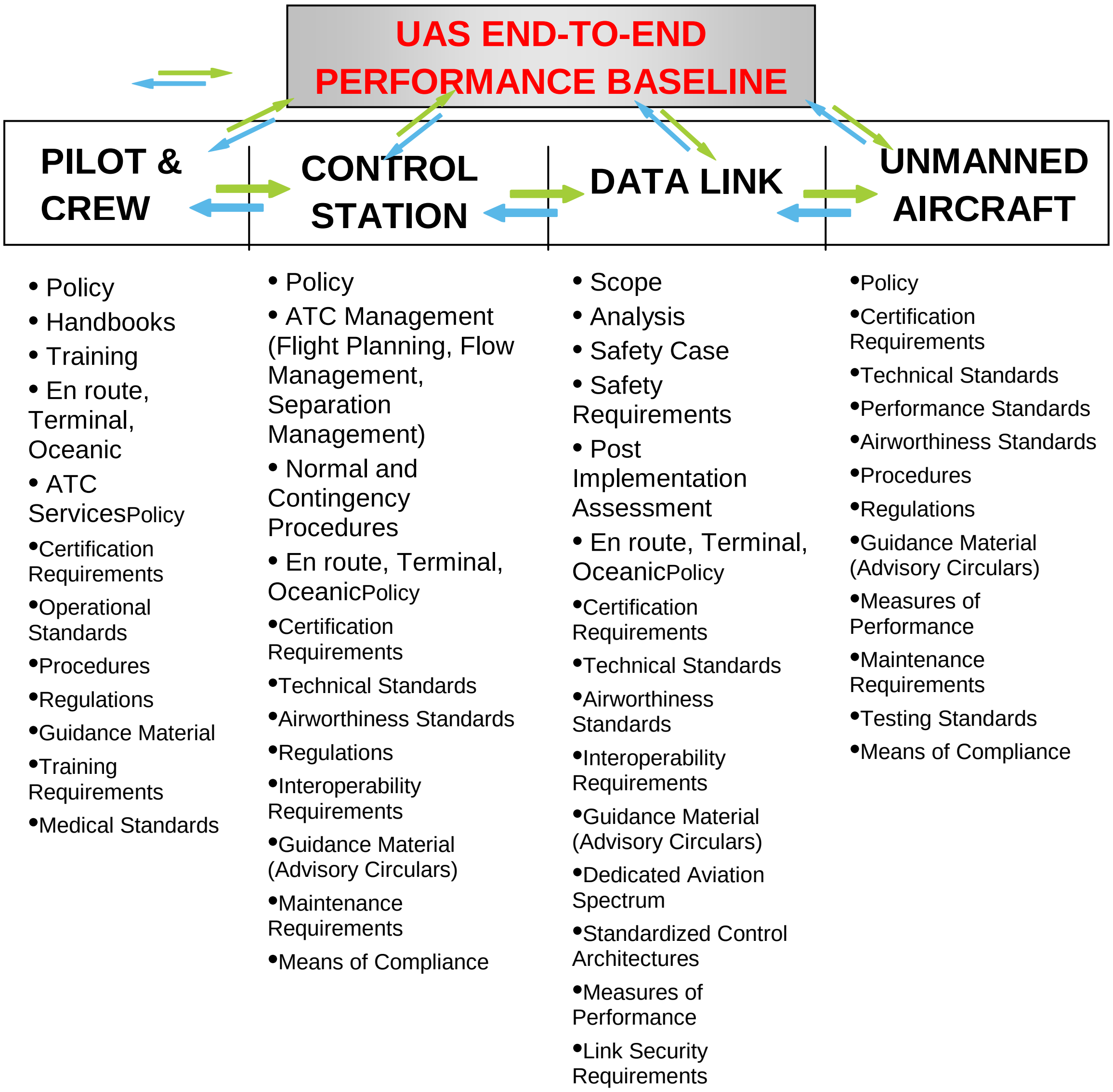


Figure A-1 Product areas relating to UAS that will require supporting research

Figure A-2 illustrates product areas relating to UAS that will need supporting research that establishes interoperability with the air traffic service provider and users of the NAS:

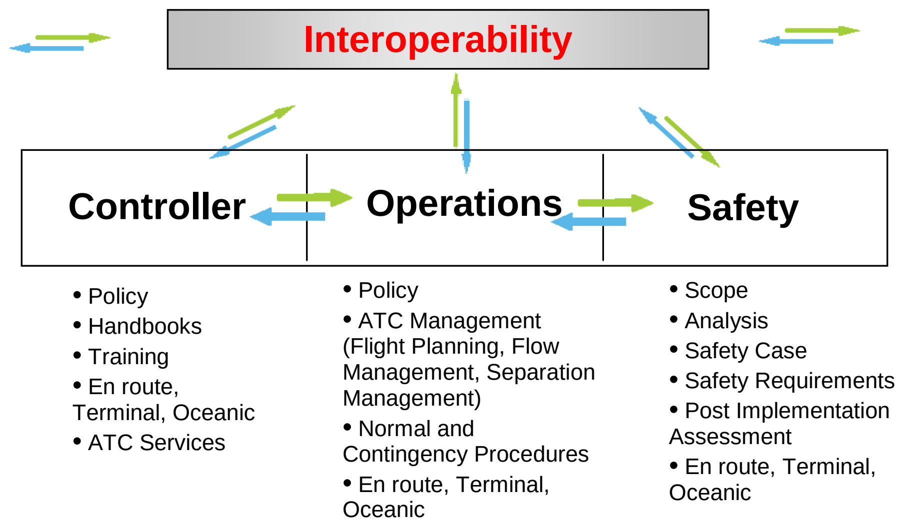


Figure A-2 Product areas relating to UAS interoperability that will need supporting research

Integration

The FAA needs a Concept of Operations (ConOps) for the integration of UAS operations in the NAS to provide the vision of how these aircraft will be integrated with other NAS operations in the NextGen environment. Following a standard system engineering process, the ConOps should be used to derive a set of requirements (technical, operational, regulatory, etc.). These concept-level requirements aid in prioritizing research activities as well as in identifying any research gaps that may exist. In addition, it provides decisionmakers a reference for assessing the concept's feasibility and relationship to other aspects of the operational environment. The NextGen UAS in the NAS RD&D Roadmap reflects how stakeholders will transition from today to the integrated vision described in the concept.

The FAA is in the process of developing a concept of operations for the integration of UAS into the NextGen NAS. The concept will describe UAS operations in the NAS from the perspective of the air traffic control and air traffic management (ATM) systems and in the context of the FAA's Next Generation Air Traffic System in the 2022-2025 timeframe. The vision for the UAS ConOps is full integration of UAS operations, with aircraft meeting the designated operational performance requirements for the airspace in which they fly. In this time period, accommodation is made only for those who cannot comply with these requirements and only when operations permit.

The long-term efforts with regard to UAS access will focus on completing the regulation, standards, certification, operational guidance, procedures, and training of the UAS established by the FAA in the near term. These efforts will include:

- FAA policy, operational guidance, and standards for civil aircraft airworthiness
- Continued airworthiness methodologies

- Training and certification standardization
- Certify key technologies to enable operations of UAS in the NAS
-

UAS operation at airports with manned aircraft operations is one of the more significant challenges to NAS integration. The UAS must be able to operate within airport parameters and comply with the existing provisions for aircraft. As with airspace operational requirements, the airport standards are not expected to change with the introduction of UAS, and their operation must be harmonized in the provision of air traffic services.

Summary of FAA UAS R&D Needs

The FAA pathway to UAS integration in the NAS was developed in conjunction with the UAS Program Office (AFS-407), ATO UAS Office (AJV-13) and the FAA NextGen Research and Technology Development Office (AJP-6) to establish a solid foundation leading to routing operations in the NAS. The following core questions provide a framework, illustrated in Figure A-3, to define a path forward:

- Define what operations/missions the operator wants to execute
- Define the performance categories of Unmanned Aircraft Systems (UAS)
- Define strategies to resolve UAS and ATC interoperability issues (flight planning, surface operations, flight concepts) through simulation and demonstrations
- Define sufficient failure mode recovery operations that are aligned with current ATC expectations

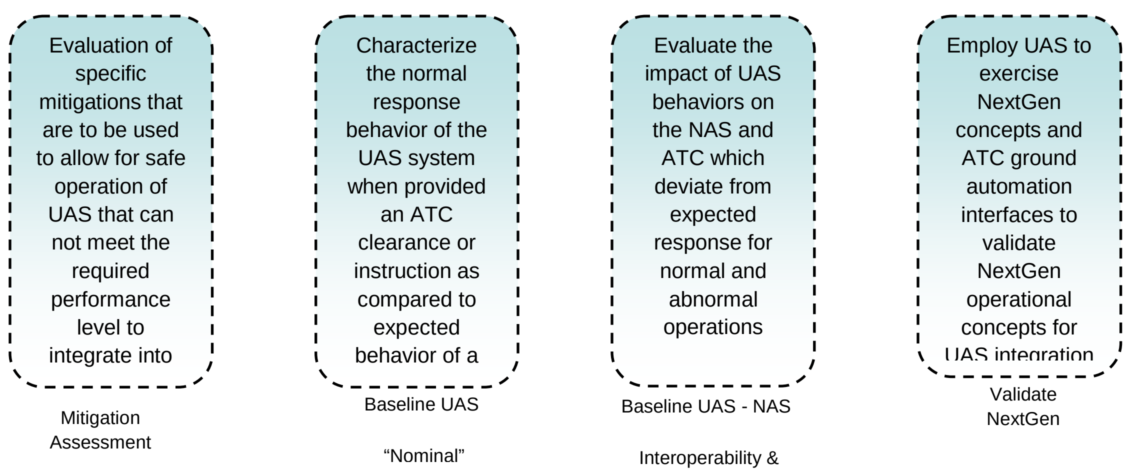


Figure A-3 Steps to UAS integration in the NAS

First, the FAA wants to baseline UAS performance to characterize normal response behavior of the UAS when ATC provides a clearance or instruction as compared to the expected behavior of a current aircraft fleet. Second, the FAA wants to baseline the contingency UAS performance to characterize system response and behavior during abnormal system functionality and recovery as compared to the expected behavior of a current aircraft fleet. Third, the FAA wants to baseline UAS interoperability to evaluate the impact on the NAS and ATC of UAS behaviors which deviate from expected responses during normal and abnormal operations. Lastly, the FAA wants to validate NextGen concepts and refine NextGen requirements.

Research Partnerships
The FAA has established a number of partnerships with industry and other organizations. The purpose of these partnerships is to ensure alignment of research efforts and products with ongoing UAS work. The FAA will engage internal and external stakeholders to coordinate needs and requirements to support future routine operations. Examples of focus areas for these partnerships include:

- 14 CFR Part 25 compliance checklist consideration
- 14 CFR Part 27 review
- 14 CFR Part 91 review
- 14 CFR Part 153 review
- Auto-land systems design and certification
- Control station design and certification

Research Efforts
The UAS community is providing support to the FAA's effort to demonstrate and evaluate planned four-dimensional (4D) automation toolsets, as well as validation of RTCA SC-203 UAS performance requirements, which are under development. This validation will allow the FAA to advance the safety case for UAS and facilitate completion of the standards and the associated guidance material (Advisory Circulars and Technical Standard Orders).

Objectives include:

- Examine potential concepts for the wide-spread integration of UAS into the future NextGen environment
- Utilize the UAS as a testbed for trajectory based concept validation
- UAS fly 4D trajectory profiles today and are equipped with toolsets (datalink, GPS) that provide the digital platform needed for 4D
- Use the advanced capabilities of the UAS community to serve as a testbed for exploring future 4D trajectory based concepts

Benefits include:

- Provide UAS operators with critical information to refine operating concepts and tools
- Provide the FAA with confidence in the safety case for UAS NAS integration
- Provide a platform for validation of RTCA SC-203 UAS performance requirements

Process for Leveraging Interagency R&D
The FAA manages its research to meet the needs of the regulator and air traffic service provider with data to support regulatory and policy development, mitigation evaluation, and definition of future requirements. This section defines an integrated and structured approach that considers both the organizational and collective UAS research needs of the JPDO partner agencies in an effort to maximize collaborations, minimize overlap, and ensure that the critical research challenges are being met. The JPDO partner agencies will use this process to consider how best to utilize research to integrate and optimize UAS operations in the NextGen NAS.

Current research efforts underway within the UAS community must be reviewed for potential applications that could satisfy specific needs. Leveraging these efforts could shorten the overall timeline to achieving satisfactory results. JPDO partner agencies will have the ability to partner and utilize finite resources in the most effective and efficient manner possible.

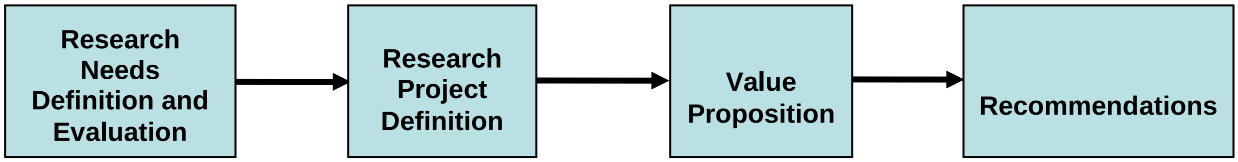


Figure A-4 Research needs definition and evaluation process

Research Needs Definition and Evaluation

In defining and executing future research, each of the JPDO partner agencies should conduct a detailed assessment of the NextGen NAS environment and envisioned UAS operations. In addition, these assessments should provide the analysis necessary to identify, define, and prioritize the research needs. This should be accomplished in a transparent manner, allowing for comparison among the agencies and grouping of research needs by similar characteristics. Identifying common needs provides for broader consideration across organizations and enables the development of joint projects and activities that meet the needs of multiple agencies.

Each agency should evaluate its stated research needs with consideration for:

- Traceability between research and validated requirements
- Project resource estimates for executing tasks efforts
- Value of satisfying stated research needs
- Challenges to satisfying stated needs

This evaluation will establish a basis for estimating project costs and benefits during later steps in the process, and will be considered during decisionmaking processes when considering solutions to address research needs.

Research Project Definition

The task definition phase consists of establishing specific activities to address identified needs. These tasks may include, but are not limited to, regulatory review, policy review, standards review, research efforts, demonstrations, technical prototyping, and modeling and simulation. Alternatives should be established that are qualitatively different from each other (e.g., different technologies, such as ground-based versus airborne solutions), and should be low risk, cost-effective, and operationally suitable. All concepts that emerge during this step will be considered, provided they satisfy the correlated needs and can be achieved without impacting the safety and efficiency of the NAS.

Value Proposition

The value proposition step will evaluate the relative benefit of achieving a given task compared to other tasks. The desired outcome of individual tasks will determine the relative value of undertaking each task. This step will provide clear metrics for each task under consideration, and it will trace directly to the needs. Considering resource constraints, this assessment will be key in maximizing value across JPDO partner organizations.

Recommendations for Research
This step involves formulating a set of recommendations to the appropriate research management level within each individual JPDO partner organization for sponsorship and execution. The recommendations must consider the alternative analyses and criticality of recommended approach, and they must include an executive summary with required resources, timelines and risks.

As a result of the needs identification and task definition processes, it may be necessary to employ research by other agencies or industry to define operational concepts, develop a set of preliminary requirements, demonstrate and refine technologies, reduce risk, or achieve consensus on potential solutions. Transparency and partnership should underline the definition of research activities undertaken by JPDO partner organizations, with the outcome being the satisfaction of the JPDO partner organizations' needs and the safety and efficiency of the NAS that includes UAS operations.

Future Updates
Once the UAS Concept of Operations vision document is complete, it will be used to assist with the generation of updates to UAS research management plans and roadmaps. The concept development process may identify additional research gaps, and it will also aid in prioritizing research activities that are directly tied to achieving the vision for UAS in the NAS.

Department of Commerce (DOC)
National Oceanic and Atmospheric Administration (NOAA)

History of Involvement with Aviation and UAS
UAS have the potential to efficiently and safely bridge critical information gaps in data from sparse and remote locations of the global environment, and advance the understanding of key processes in earth systems. Optimizing the capabilities that UAS offer will advance the National Oceanic and Atmospheric Administration's goals through improved understanding of oceanic and atmospheric exchanges, hurricanes, wildfires, marine ecosystems, polar regions, hazards, and other environmental and ecological processes, ultimately leading to improved climate and weather predictions and better management of marine resources.

NOAA is partnering with other civilian agencies, industry, and the academic community to develop UAS operations, systems, and platforms that can be safely deployed, both nationally and globally, to fill observational data gaps with increased efficiency and decreased risk to personnel.

The UAS program began as a major project within NOAA's Office of Atmospheric and Oceanic Research in FY05. Formal program funding began in FY08 with a total of $15 million received during FY08-FY10. Over this time, the UAS program has managed a diverse investment portfolio that has developed tools and practices needed to build NOAA capacity and expertise with UAS technology. UAS program activities include demonstrations of platform capabilities such as long endurance or low altitude, airspace coordination with the FAA, and sensor development. Investments have also been made in the development of observing system simulation experiment capabilities. This way the impact of UAS observations on weather and climate prediction may be assessed against current operational observing assets.

The UAS program has conducted conceptual demonstrations of UAS platforms and payloads of varying technology readiness and maturity. Regional testbeds based in the Arctic, Pacific, and Gulf/Atlantic were used as incubators for concept studies focused on NOAA observing needs. NASA and NOAA conducted the first civilian science missions with the Global Hawk UAS as part of this joint field experiment.

Primary Challenges and Objectives
Timely, accurate, comprehensive, and integrated earth observations are vitally important for NOAA to accomplish its mission. Yet, to ensure NOAA is employing the most cost effective and operationally efficient observing solutions, regular evaluation of newly emerging observing technologies is necessary. UAS are new observing systems that offer advanced capabilities to meet crucial observing needs highlighted within several of NOAA's science plans.

The primary programmatic risks identified are access to airspace, availability of spare parts, and inadequate funding. NOAA states that the lack of file-and-fly UAS operations in the national airspace prevents NOAA from achieving significant savings anticipated from replacing manned missions with unmanned missions where possible. The access to airspace is a risk across all platforms and is currently being addressed by the FAA. FAA approval of UAS access to national airspace is currently granted on a case-by-case basis with a Certificate of Authorization (COA), which is a lengthy, labor-intensive process and will not have low-altitude UAS rules for NAS access until 2012**.** To address this issue, the NOAA UAS program will support the integration of UAS into the NAS and allocate resources to ensure expedient processing of COA with the FAA for upcoming missions. Our objective in supporting the NextGen UAS Roadmap and Research Management Plan is to assist the process of full UAS integration in NextGen in order to move forward with our plans to modernize operations**.**

Scope of Investment in UAS
UAS performance capabilities are designed to provide critical real-time information allowing NOAA to accelerate understanding and prediction of rapidly changing polar, marine, and high-impact coastal weather events. UAS will be able to extend flight ranges, altitudes, and endurance performance of the NOAA aircraft fleet to better meet NOAA observational needs. UAS could also provide extended critical gap-filling observations during periods of satellite malfunction. NOAA investments in the UAS program have significantly enhanced knowledge of and experience with UAS technologies so that future acquisition and operational implementation decisions will be well informed. DOD, NASA, and other federal agency investments have significantly matured the technology readiness of UAS, which in turn reduces the development risk for NOAA and allows a greater emphasis on transition into operations.

The NOAA UAS program team has developed a five-year strategic plan. This plan outlines a path forward to improving high impact weather, polar, and marine monitoring using UAS technologies. In the near term, recent UAS program accomplishments demonstrating the feasibility and technology readiness of the high-altitude, long-endurance Global Hawk and low-altitude, short-endurance UAS such as the PUMA offer opportunities for transition into operations during the FY14-FY15 time frame. The UAS program is prepared to develop UAS pre-operational observing strategies for hurricanes, Pacific winter storms, Arctic weather, and polar sea ice using the Global Hawk through a partnership with NASA. This approach allows NOAA to share cost and risk with NASA while providing greater access to Global Hawk assets dedicated to NOAA missions, and preventing schedule conflicts with the Global Hawk dedicated to NASA missions. Incubating and integrating low-altitude, short-endurance, hand-launchable UAS capabilities into NOAA operations will extend the observing ranges of ground observers and ships, and address rapid response needs of coastal, marine debris, fisheries law enforcement, and wildlife monitoring.

The information and experience gained by the UAS program provides a firm foundation to develop and implement a roadmap for transition of UAS technologies to application within NOAA. The UAS program will adopt the NOAA Process for Transition of Research to Applications and is an ideal candidate to develop new missions. The program has confirmed that a wide variety of UAS technologies and observations offer substantial benefits to NOAA. Yet, progression of transition to operations cannot be accommodated by a simple acquisition of a specified number of UAS assets that are transferred to fleet operations. Some UAS capabilities, such as high altitude or long endurance, are unique when compared to the current NOAA observing capabilities; near-term benefit should be expected within a few years. However, other categories of UAS platform or payloads need further system analysis and testing to either optimize observing strategies or to take advantage of economies of scale across science themes or NOAA priorities.

The UAS program will employ a mission development (MD) process to innovate and integrate UAS capabilities for operational implementation. This process is similar to procedures commonly used by other federal agencies for large research and development efforts such as spacecraft development and deployment. The UAS process for mission development and transition to operations will be comprised of four main steps, with the execution of a key decision point after each step to assess technology readiness and feasibility for both science and operational benefit. The four steps of the process are to identify promising technologies, optimize observing strategies, test and optimize a Concept of Operations, and transition into operations.

The importance of employing a mission development process is to establish credibility for UAS technologies as they mature toward operations, and to facilitate early collaboration with NOAA end users of UAS technologies. This will ensure effective operational schedules, budgets, and staffing plans are in place before operational implementation.

DOC Involvement and Respective Roles

NOAA

NOAA's UAS R&D is focused on UAS mission technology and procedures, not UAS technology or integration. For the operation of UAS in conjunction with science and weather missions, UAS can help NOAA meet its mission goals with a more advanced fleet capable of collecting data. Specifically, UAS may:

- Extend hurricane landfall lead times by observing storm environments

- Improve the accuracy of storm forecasts, benefitting emergency managers and diverse private industries, from energy and tourism to airlines
- Improve climate change understanding
- Assess Arctic ice change and effects on ecosystems and coasts
- Improve flood and drought forecasts, helping water managers
- Increase safety and success in fighting wildfires that threaten people and property
- Monitor coasts and oceans—environments important for fish and marine sanctuaries

International Trade Administration Manufacturing and Services

Manufacturing and Services (MAS) is a unit of the DOC's International Trade Administration (ITA). The MAS aerospace team's mission is to advance the international competitiveness of the U.S. aerospace industry, including UAS, by leveraging its in-depth sector and analytical expertise in the development and execution of trade policy and promotion strategies. The MAS aerospace team works to promote U.S. policies that strengthen the international competitiveness of the U.S. aerospace industry, provide advice to help aerospace companies penetrate new markets, increase market share, resolve specific market obstacles, and provide industry analysis to the U.S. business community, policy makers, and trade negotiators. The goals of MAS's UAS activities are to:

- Show the importance of the UAS industry to U.S. jobs and exports, identify key export markets, and identify policy actions that ITA can take to enhance industry competitiveness
- Promote the health of the U.S. UAS industry as an export platform by encouraging UAS commerce and a regulatory environment that supports a viable UAS market for public use and civil UAS applications that operate safely and routinely in the NAS
- Develop export markets for domestically produced UAS technology

The civil and military UAS market is projected to grow rapidly over the next decade, with the civil market developing more slowly than the military market. The UAS industry can help achieve the President's National Export Initiative (NEI), the goal of which is to double U.S. exports by the end of 2014 and support millions of U.S. jobs. The NEI aims to support jobs by increasing the number of companies exporting, and expanding the number of markets to which U.S. companies sell. Key NEI export markets include India, Brazil, China, Russia, Canada, Japan, the European Union (EU), Korea, Turkey, and the Gulf Region (including UAE and Saudi Arabia). The aerospace team's UAS-specific activities include:

- Advocacy and outreach on behalf of U.S. companies selling to foreign governments
- Collaboration with industry associations to promote UAS exports
- Quantifying the market impact of civil UAS in order to promote greater airspace and spectrum access, and align international standards

More information is available at www.trade.gov/mas/manufacturing/OAAI/.

Department of Homeland Security (DHS)

History of Involvement with Aviation and UAS

America's borders encompass over 19,800 statute miles, 12,300 of which are coastline. To ensure security along these borders, the Department of Homeland Security (DHS) and Other Government Agencies (OGAs) employ a comprehensive "layered security" strategy. This strategy seeks to provide security at and between U.S. ports of entry, while simultaneously extending the zone of security beyond the physical border, including the waters surrounding the U.S. landmass. Extending law enforcement and security along our extensive land border and beyond our shores and into the maritime domain is critical because the safety and economic security of the U.S. depends in substantial part on the secure use of the world's oceans. This extended border security strategy requires innovative approaches, one of which is the employment of UAS in law enforcement and homeland security applications.

The U.S. Border Patrol began considering the utility of UAS in the late 1990s. Following the September 11, 2001 terrorist attacks on the World Trade Center and the creation of the DHS, from 2004 to 2005 DHS's Customs and Border Protection (CBP) office experimented with two UAS—the Israeli Hermes and Northrop Grumman's Hunter—along the U.S. southwest border. After this initial evaluation, CBP selected General Atomics' Reaper/Predator B and began operations in October 2005.

Today, CBP has a fleet of seven Predator Bs conducting operations along the northern and southern U.S. borders (Figure A-5). These vehicles are equipped with the Raytheon Multi-spectral Targeting System–B (MTS-B) electro-optical sensor and the Lynx synthetic aperture radar.

Figure A-5 Customs and border protection UAS operating areas

Encouraged by its land border success, and faced with the challenge of maritime homeland security and law enforcement across the nation's vast coastline, DHS is addressing its mission requirements by expanding UAS operations into the maritime domain with a maritime Reaper UAS variant called "Guardian," operated by CBP and the United States Coast Guard (USCG). Their joint maritime UAS ConOps envisions basing the UAS at CBP Operating Centers (OCs) and Forward Operating Locations (FOLs), and conducting operations primarily in the southeast U.S./Northern Caribbean, the Great Lakes/St. Lawrence Seaway, and the Transit Zone. The Guardian is tasked with providing persistent wide-area surveillance (WAS) of open seas, littoral waters, and inland seas with multi-spectral sensors and networked data links. Sensors are used during all mission phases for air navigation, hazard avoidance, and Air Traffic Services compliance. Once in the mission area, the maritime UAS performs surveillance, detection, and classification mission tasks, and supports identification and prosecution tasks. Mission payload data are transmitted to compatible ground teleports and injected into federated networks using standardized protocols for further dissemination to supporting vessels, aircraft, and exploitation sites.

This improved Maritime Domain Awareness (MDA) increases the effectiveness of CBP and OGAs in performing their core homeland security, defense, civil support, and law enforcement missions.

Primary Challenges and Objectives

Small UAS

Small, hand-held Unmanned Aerial Systems (SUAS) offer a quick response capability and a timely local-area situational awareness tool for first-responder personnel throughout the U.S. These craft are currently in operation with DOD supporting platoons, squads, and companies, including special operations and ground troops. The systems have flight durations of less than two hours and are highly transportable.

The small size of these platforms impacts the overall performance of the available sensors. Additionally, the platforms are reactive to wind gusts, and in some cases the electro-optical and infrared sensors are in a fixed position due to limited integration locations and payload capacity. The combination of the fixed location and the reaction to gusting results in an unstable collection of data through these sensors. A gimbaled platform for the sensor facilitates operational flexibility and the acquisition of clearer images for the analyst.

Integrating these platforms into the NAS is a broad challenge that applies to all sizes of UAS platforms. Several organizations are working with the FAA to identify a technical approach to help integrate unmanned systems with manned aircraft. These efforts include modeling and simulation to determine the probability of an encounter with another aircraft, using radar either on the ground or on the UAS to increase situational awareness. In 2007, the DHS Science and Technology (S&T) Directorate created a multi-year, multi-agency modeling and simulation program, led by MIT's Lincoln Laboratory, to build the FAA-mandated safety case required for collision avoidance. In the near-term, 2011-2012, this effort will demonstrate the feasibility of a scalable, low size, weight and power airborne sense and avoid prototype system. The long-term goal of UAS access to the NAS will be helped by integrating ADS-B transceivers on most aircraft as part of NextGen.

Medium UAS

DHS is currently using medium-altitude UAS as part of their operations. The primary objective for this class of system is to identify and evaluate candidate sensor technologies for the ever-changing threat. These capabilities include wide-area surveillance, tracking of displaced personnel, identification of ultralights, and identification of self-propelled semi-submersibles and propelled submersibles.

Wide-area surveillance solutions have increased rapidly over the last couple of years. These solutions allow operators and analysts to monitor a fixed area in real-time and conduct forensic analysis over the same area within 24 hours. The technology results in the ability to track vehicles throughout the scene and in some limited cases to track dismounted individuals. Future enhancements will allow a wider area to be surveyed with greater fidelity, with long-persistence UAS as a key tool for maximizing the effectiveness of wide-area surveillance sensors.

Moving target indicator technology with radar systems is now resulting in the capability to track dismounted individuals. The radars are small enough to be carried by a medium UAS. Several demonstrations funded by CBP have already taken place along the southwest U.S. border. DOD and DHS are both interested in furthering the technology maturity and integrating the solution on existing platforms.

Long-Endurance UAS

Mature long-endurance UAS do not exist today. Funding between DOD and DHS is helping increase the technical maturity of airship and winged designs. Both agencies are interested in platforms that could provide intelligence, surveillance, and reconnaissance data over an area for greater than five days without having to rely on space-based assets.

After a platform is sufficiently developed, sensor integration will be the next step. These sensors must be able to operate at high altitude—greater than 40,000 feet—and in cold temperatures. Additionally, the data from these sensors should insert into the current communication architecture and be available in near real-time. Funding will be necessary to investigate candidate sensor technologies though ground and flight testing.

Scope of Involvement and Investment in UAS

Small UAS

Within the United States, five recent attempts to assess the feasibility of integrating SUAS into first responder operations included five large cities between 2006 and 2009. Each of these cases highlighted the difficulty in complying with FAA regulations on flying SUAS in populated areas; only two received FAA approval and were actually flown, though not in urban areas.

Another major issue that surfaced was the relatively high price to purchase and operate these systems. The primary customers for UAS to date have been the military and other government organizations with large budgets. For county or city entities to become potential users of these systems, they must be able to both justify their use and afford the cost. In the case of the Houston demonstration, the media portrayed the effort as secretive and resulting in unsolicited drone surveillance—a misrepresentation that was unacceptable to some of the public.

DHS S&T funded a flight-test demonstration with the Los Angeles Sheriff's and Fire Departments to determine the utility of small hand-launched, fixed-wing UAS in various first responder missions. A key aspect of the demonstration was to determine the likelihood of gaining FAA certification to fly the small platforms in an urban environment. Four locations were identified as possible test locations. Due to concerns about flying near populated areas, the FAA approved Certificate of Authorizations only for two areas.

Successful demonstrations occurred during the summers of 2010 and 2011 at the two locations. The SUAS were able to perform first-responder missions including locating individuals (using visual and infrared sensors), determining individual intent, detecting personnel in a search and rescue situation, and identifying radiological hazards in the environment.

DHS also conducted a field test of several SUAS to determine their operational utility. They were able to duplicate the fixed sensor issues identified in the previous section. Their analysis further substantiated the need for both gimbaled electro-optical and infrared sensors on the platforms for operational effectiveness.

Medium UAS
DHS and USCG will continue to invest in the Predator/Guardian class of UAS for border and maritime protection. A long-term acquisition strategy exists that details the plan to grow the fleet and upgrade the sensors necessary to meet future mission requirements. DHS is interested in leveraging some work that the Air Force Research Laboratory has recently accomplished with a segment of UAS smaller than the Predator/Reaper class. These UAS have the ability to fit into an available need with tactical personnel on the ground. The UAS would provide personnel with the ability to survey the local area in quick response to threats. USCG is also interested in this class of UAS to provide ship-borne surveillance of the area nearby their maritime craft. These UAS would support the various missions that the next-generation vessels will undertake.

Long-Endurance UAS
The DHS S&T Directorate invested over $5 million into a long endurance (five to seven days) UAS flight. Long-endurance systems, either winged or airship, can provide DHS with expanded surveillance over one area or along a border, or can enhance communications by relaying information from a high altitude. S&T is interested in funding demonstrations to showcase the capability and identify sensor and/or communication payloads that will enhance operational performance.

One candidate program was in the midst of flight test during the spring of 2011. A software command and control error may have been responsible for the loss of the platform. S&T will continue to monitor the progress of the program and commit funding, when appropriate, to further DHS interests in this emerging capability.

Department of Defense (DOD)

History of Involvement with Aviation and UAS

The military has been interested in applying concepts of UAS since the beginning of aviation. Starting in 1915, the Navy was interested in using the concept for a pilotless bomb, and for decades used UAS for gunnery practice. The Army Air Service also saw potential in the aerial torpedo concept. The “Bug” is recognized as the first unmanned aircraft to go into production, as 36 of them were produced in Dayton, OH.

During WWII, the Navy purchased over 15,000 radio planes for their anti-aircraft gunners through the OQ-1 as it evolved into the OQ-17. The OQ-17 evolved into the OQ-19, of which the Army acquired 48,000 over the course of almost 40 years. The OQ-19 was also the platform for the Army SD-1 as the world’s first reconnaissance UAS.

During Vietnam, the Air Force flew 23 versions of the Special Purpose Aircraft (SPA) AQM-34 Lightning Bug in 3,435 sorties to conduct reconnaissance, intelligence, and other missions. The Navy pursued a helicopter design, the QH-50, for anti-submarine warfare, surveillance, and cargo transfer.

During Desert Storm, the Pioneer was used to assist the Navy to acquire targets and direct naval gunfire. In the 1990s, Advanced Concept Technology Demonstrations (ACTDs) allowed the DOD to acquire new technology quicker and at lower cost than the traditional acquisition process. In1994, the new process allowed for the acquisition of the General Atomics Predator UAS and Global Hawk.

Though the missions and naming conventions have evolved over the decades, the interest in unmanned aircraft has only gotten stronger as they become even more capable. UAS continue to provide capabilities to the warfighter as a force multiplier. They are widely used in contingency operations in Iraq and Afghanistan. The dramatic range in size and capabilities make them uniquely able to perform certain missions not suited for manned aircraft.

Roles in UAS Operations

DOD UAS have become a critical component of military operations. Title 10 of the United States Code, the legal underpinning for the roles, missions, and organization of DOD, provides authority for military departments to organize, train, and equip U.S. forces, fulfilling the core duties for national defense. Consistent with this statutory authority, longstanding practice, and as reinforced by interagency agreements, DOD is responsible for establishing airworthiness requirements and ensuring rigorous military standards are satisfied for the entire aircraft system, including the airframe, control stations, communication links and onboard sensors.

DOD establishes its own pilot/operator and maintenance training/qualification requirements. It has outlined the basic aviation knowledge and required skills for pilot/operator certification for each UAS group and/or unique UAS to fly in certain airspace. The military departments have also established safe operating procedures for combined manned and unmanned airfield operations and applied predictable contingency procedures. DOD plans to apply those lessons learned as it continues to expand in the NAS.

DOD uses their UAS to perform operational, training, and support missions. They need to execute operational tasking, typically from a Combatant Command (COCOM), such as the United States Northern Command (NORTHCOM), to perform tasks such as maritime operations and disaster or special event support. In Iraq and Afghanistan, U.S. Central Command (CENTCOM) use UAS extensively for intelligence, surveillance, reconnaissance (ISR), communications relay, force application (engagement/precision strike), protection, and logistics.

The Services and appropriate COCOMs need to conduct realistic UAS and integrated training in the NAS prior to operational missions to maintain a high degree of combat readiness. To meet these requirements, military departments and COCOMs must maintain proficiency in areas such as line-of-sight operations, launch/recovery operations, ISR operations, ground-target tracking, and night operations.

Support missions primarily involve UAS development and acceptance testing, and post-maintenance check flights. These missions also include the development and integration of payloads into the UAS, verifying procedures, ferry flights, and other missions that are not dedicated operational or training missions.

Primary Challenges and Objectives
In order to realize the full potential offered by UAS, some major challenges must be overcome: interoperability, autonomy, airspace integration, communications, and manned-unmanned teaming. Part of these challenges is the overarching issue of making these systems affordable.

Interoperability. Interoperability can serve as a powerful force multiplier, improving joint warfighting capabilities, decreasing integration timelines, simplifying logistics, and reducing total ownership costs.

Autonomy. The rapid proliferation of unmanned systems has created a manpower burden on the military departments, who are seeking ways to improve the efficiency of operations. Introducing a greater degree of system autonomy has the potential to significantly reduce the manpower burden.

Airspace Integration. The rapid increase in fielded UAS has created a strong demand for access within the NAS and international airspace. The demand for airspace has quickly exceeded the current airspace available for military operations. NAS access for UAS is currently limited primarily due to regulatory compliance issues and interim policies. DOD UAS operations conducted outside of restricted, warning, and prohibited areas are authorized only under a temporary COA from the FAA. The COA process is adequate for enabling a small number of flights, but does not provide the level of airspace access necessary to accomplish the wide range of DOD UAS missions at current and projected operational tempos. This constraint will only be exacerbated as combat operations in Southwest Asia wind down and systems are returned to U.S. locations.

Communications. Current unmanned systems' operations involve a high degree of human interaction with the systems via various means for command and control (C2), and transmission of operational data. Protection of these communication links and the information flowing through them is critical to operations. As the number of fielded systems grows, communications planners face challenges such as communication link security, radio frequency spectrum availability, deconfliction of frequencies and bandwidth, network infrastructure, and link ranges.

Manned-Unmanned (MUM) Teaming. MUM teaming refers to the relationship established between manned and unmanned systems executing a common mission as an integrated team. U.S. military forces have demonstrated early progress in integrating unmanned systems within the existing manned force structure, but much more needs to be done to achieve the full potential offered by unmanned technology. Improving MUM teaming is both a technology challenge in connecting the systems and a policy challenge in establishing the rules of engagement for operating semi-autonomous unmanned systems along with manned systems.

Scope of Involvement and Investment in UAS

UAS continue to prove their value in Iraq and Afghanistan, where military operations are planned and executed in extremely challenging environments. Adversaries are fighting using increasingly unconventional means, taking cover in the surrounding populations, and employing asymmetric tactics to achieve their objectives. UAS will be critical to U.S. operations across a range of conflicts, both because of capability and performance advantages, and the ability for unmanned systems to take greater risk.

DOD has become increasingly reliant on UAS, as shown by the flight hours in Figure A-6. DOD will continue to support diverse mission sets and capabilities, but must focus on acquiring joint and interoperable platforms, systems, software, architecture, payloads and sensors. In addition, the ability for commanders to take risks with unmanned vehicles depends significantly on their cost.

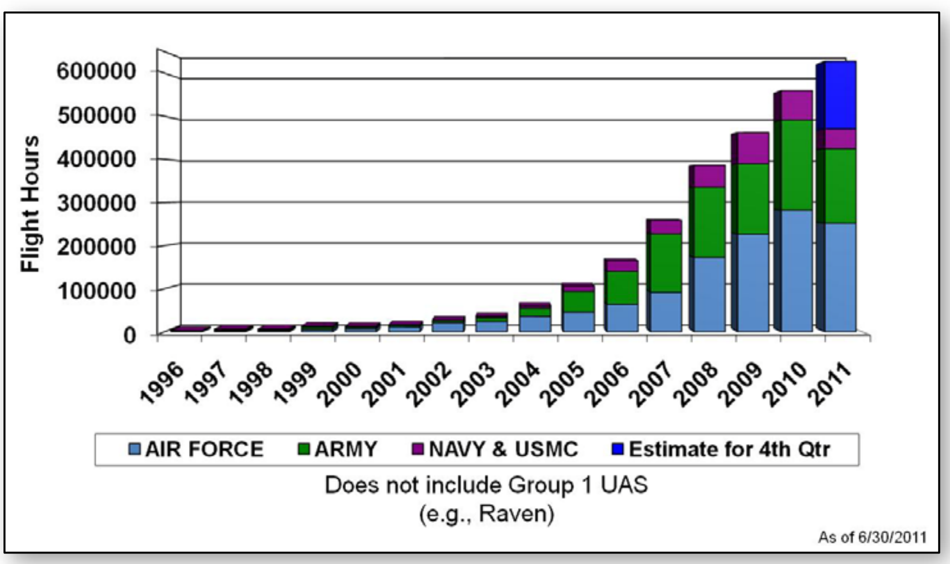


Figure A-6 DOD UAS flight hours

The DOD will look at capitalizing on commonality, standardization, and joint acquisition strategies. The importance of procuring common platforms with core command and control systems will yield enormous collective benefits by reducing training costs, reducing supply chain diversity, improving availability, and offering a cost-effective procurement path by exploiting the benefits of scale and software/technology reuse. Also, the Department demands these systems be affordable by assessing the development and production lifecycle cost at the outset, with no significant cost growth in their development and production evolution. UAS investments have allowed DOD to field a large number of UAS capable of executing a wide range of missions. A decade ago, UAS missions focused primarily on tactical reconnaissance; however, this scope has been expanded to include most of the capabilities within the intelligence, surveillance, and reconnaissance (ISR) and battlespace-awareness mission areas. UAS are also playing a greater role in strike missions as the military departments field multiple strike mission-capable weapon systems for time-critical targeting. Figure A-7 illustrates the variety of platforms in today's force structure.

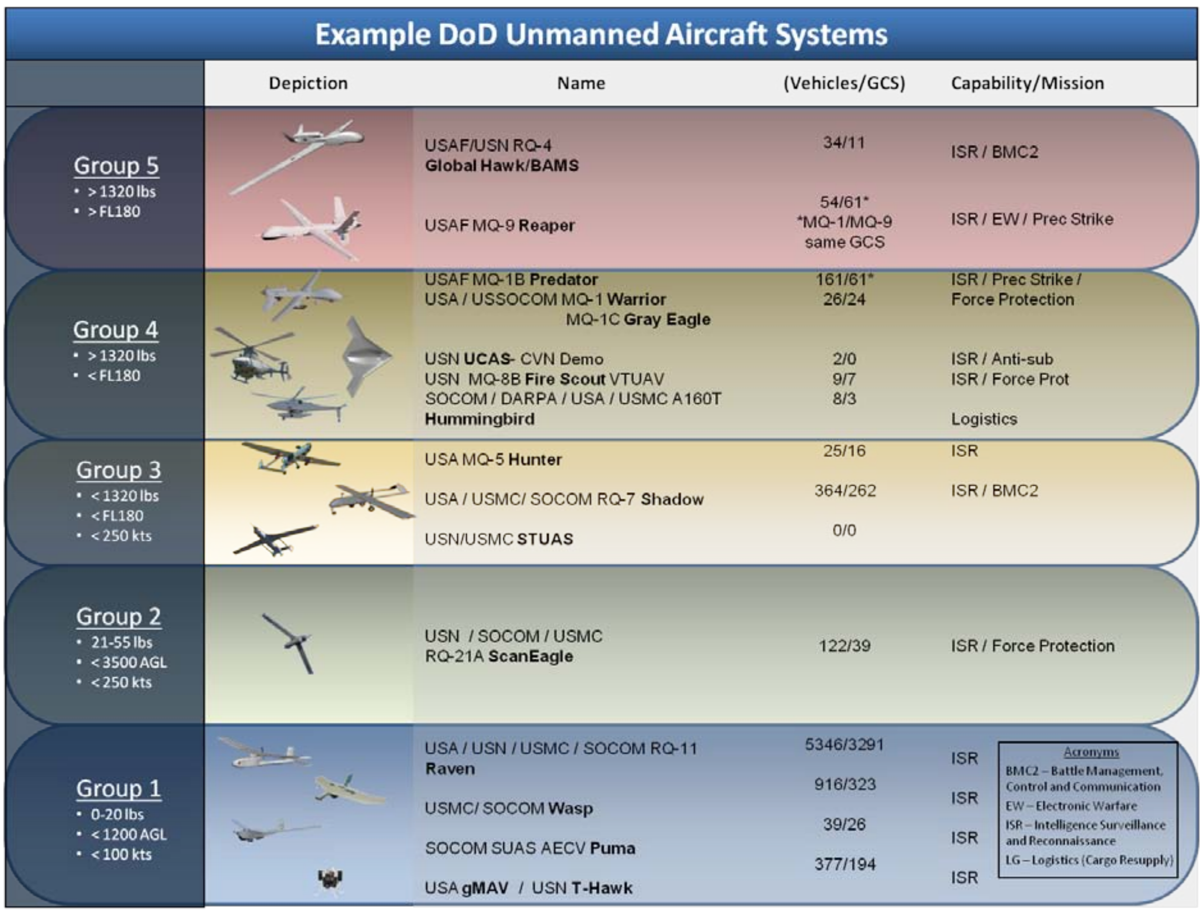


Figure A-7 DOD UAS types

Involvement and Respective Roles

There are many stakeholders within the DOD that are affected in some capacity by UAS and airspace integration issues. In addition to the Services, the following organizations are considered to be key internal DOD stakeholders:

Office of the Undersecretary of Defense (OUSD) Acquisition, Technology and Logistics (AT&L): The OUSD UAS Task Force was established in 2007 and dedicated to the acquisition, development, and integration of UAS into the Services under the direction of OUSD (AT&L). The Task Force is responsible for the Unmanned Systems Roadmap and other unmanned aviation-related products that influence DOD-wide UAS acquisition and technology decisions on airspace integration.

Policy Board on Federal Aviation (PBFA): The DOD PBFA, established by Executive Order, is responsible for coordinating DOD and FAA common requirements, and serves as the DOD liaison with the Department of Transportation (DOT) and the FAA on federal air traffic control and airspace management. The PBFA provides policy and planning guidance for comprehensive airspace planning to ensure that the military has sufficient airspace to fulfill operational, training, and test and evaluation requirements, cooperate with the FAA for the effective and efficient management of the NAS, and ensure operational interoperability between DOD and the FAA.

Combatant Commands (COCOMs): COCOMs are established to provide effective command and control of U.S. military forces, regardless of branch of service, in peace and war. Geographic COCOMs, such as NORTHCOM, SOUTHCOM, PACOM, and CENTCOM, all are dependent on UAS for operations for various reasons including their Intelligence, Surveillance, and Reconnaissance (ISR) and weapons capabilities.

U.S. Special Operations Command (USSOCOM): USSOCOM is responsible for the acquisition and employment of UAS for special operations forces. Its lead component command for UAS, including UAS airspace management, is Air Force Special Operations Command (AFSOC). USSOCOM controls its own acquisition budget independent of the Services, predominately acquiring small UAS and SOF-unique payloads and modifications for larger UAS.

Service UAS Program Offices: Each Service’s UAS program office is responsible for the development, acquisition, and sustainment of Service UAS programs of record that address approved Service requirements.

National Guard: As part of their mission, the National Guard will need to perform UAS-related missions within civil airspace. These will include both operational and training activities.

Defense Standardization Program Office (DSPO): The DSPO is responsible for the development and use of standards across DOD. Where possible, it coordinates the adoption of consensus industry standards for military use.

Envisioned Role in Interagency R&D

DOD is leading development of UAS and using them for the widest range of operations, and therefore needs to ensure its roles, missions, and characteristics are considered for NextGen operations. It actively participates within the JPDO to meet NextGen equipment capabilities and operational timelines.

As identified in the Department's UAS Airspace Integration Plan, the development of key sensor technologies will help the Department's UAS integrate seamlessly into the NAS. Those sensors may include radars (both ground-based and onboard the UA), and electro-optical/infrared (EO/IR) sensors. ADS-B may also be used in conjunction with these sensors to maximize safety. DOD is funding the development of an affordable common, autonomous airborne Sense and Avoid (SAA) system for the Air Force RQ-4B Global Hawk (GH) and Navy Broad Area Maritime Surveillance (BAMS) UAS. They have the potential to provide future capability for the MQ-9 Reaper and MQ-1C Gray Eagle.

AFRL’s current technology development and involvement in flight testing of experimental airborne SAA systems is continuing and is now emerging in DOD program developments. The Navy is leading development of a joint solution and building upon AFRL and Global Hawk technology efforts to develop a pilot-in-the-loop capability, which will then be leveraged to develop an autonomous SAA capability for GH/BAMS. Other longer-term technology options that will improve SAA include ADS-B implementation in the NAS.

NextGen requirements may pose significant cost increases for UAS operations. In addition to equipage requirements such as ADS-B, UAS must be able to meet required performance capability mandated through NextGen. The benefits of increased efficiency and safety must be balanced within reasonable costs.

Supporting the NextGen UAS Roadmap and Research Management Plan will assist the process of full UAS integration in NextGen and ultimately allow dynamic UAS operations in the NAS. Through the UAS Task Force and the UAS ExCom, DOD is continuing to interface with the FAA, NASA, and DHS with the potential for partnering in future technology efforts.

National Aeronautics and Space Administration (NASA)

History of Involvement with Aviation and UAS

UAS have become an essential portion of NASA’s research and operational capability portfolios. NASA is performing system-level research addressing critical barriers to routine access for UAS in the NAS. Additionally, NASA uses UAS to test key technologies from its Aeronautics Research Mission Directorate (ARMD), as well as to obtain critical science data for its Science Mission Directorate (SMD). UAS operations from NASA’s Dryden Flight Research Center have assisted in fighting wildfires, and NASA research capabilities in software, trajectory operations, and testing provide additional expertise to acquire data needed to make decisions and mature UAS capabilities. As NASA, other government agencies, and the private sector invest more money into UAS technologies, the need to optimize UAS access to the NAS grows.

NASA has been developing and using UAS in support of its mission since the 1960s. One of the agency’s more prominent recent projects was the Access 5 project. Access 5 was a collaborative effort between government and industry designed to develop the technologies and procedures necessary to enable routine UAS access to the NAS. Through the collaborative efforts of Access 5, the FAA created the Unmanned Aircraft Program Office (UAPO). Additionally, Access 5 led to the establishment of RTCA Special Committee 203 (SC-203). SC-203 was formed to help assure the safe, efficient, and compatible operation of UAS with other vehicles operating within the NAS.

SMD's mission is to engage the nation's science community, sponsor scientific research, and develop and deploy satellites and probes in collaboration with NASA's partners around the world. This helps answer fundamental research questions requiring both orbital and suborbital views. SMD recognized the potential for UAS to fill gaps within their existing suborbital measurement capability, and through its Airborne Science Program has invested in UAS technology since 2000. Some of the earlier investments included several flight-demonstration missions using a variety of different platforms. They involved many of NASA's partner agencies. In support of growing interest from the science community in the potential science benefits associated with UAS, SMD acquired the SIERRA UAS and three pre-production Global Hawks. SMD has since flown many UAS missions in the NAS (350+ flight hours). Additionally, SMD has acquired a vast amount of experience in defining the current and future mission characteristics required to obtain essential science data within the international community. This experience has led to expertise in developing the safety case for NASA COA applications.
All UAS flight operations conducted by NASA currently require a COA to access the NAS. On average, NASA has had 10 to15 COAs a year for the last three years to allow flights to be conducted. For SMD, this has been the primary challenge to their ability to achieve the scientific objectives of the UAS mission they support. Because the science missions are very complex and require a significant amount of airspace, the COA application process takes a considerable amount of time, and restrictions within the resulting COAs can often curtail the amount of science that can be obtained. To date, SMD has been successful in obtaining the required COAs and has been able to work with the restrictions imposed on the operations. However, there is a perception in the greater science community that it is extremely difficult to get access to the airspace, and therefore many scientists do not submit proposals that would have a requirement for UAS flights because they believe it is too difficult.

To assist with communications with the FAA and understanding of the airspace challenges, SMD has had a staff position in the FAA's UAS Program Office since 2008. The position has been very effective in transferring NASA expertise to the FAA and in helping NASA understand the highest priority FAA issues with respect to UAS safety. SMD has also provided key leadership in the FAA's Small UAS Aviation Rulemaking Committee.

NASA's recent operational history with UAS has provided significant insight into the complexities of the current COA process, as well as developing a technical community in the agency that understands the challenges of integrating UAS into the NAS. NASA's ARMD recently set the Integrated Systems Research Program (ISRP) in motion to focus on definitive results-driven projects requiring complex solutions. The UAS Integration in the NAS Project is just such a project. This project will utilize NASA's expertise in areas such as modeling and simulation, communication, software design, development; as well as verification and validation of complex integrated systems, human factors, system safety expertise of complex flight systems, flight research instrumentation expertise, and flight operational and safety expertise for all classes of UAS.

Roles in UAS Operations

NASA's primary roles in UAS operation are management, operations, and research and development. It is not a regulatory agency but does provide inputs to regulatory groups, such as the FAA. Data gathered from the UAS integration in the NAS project is closely coordinated with other NASA aeronautics programs and provided to the relevant stakeholder. NASA ARMD's ISRP is focused on carefully coordinating its project deliverables with partners in order to ensure the stakeholder is receiving the information required to make informed decisions with respect to regulations and procedures that will be used to effectively integrate UAS into the NAS.

The ISRP's goal for UAS integration in the NAS is to contribute capabilities that reduce technical barriers related to the safety and operational challenges associated with enabling routine access to the NAS. NASA ARMD is investing approximately $30 million per year through 2016 to fulfill its goals relative to UAS integration in the NAS. The project will expand on NASA's operational experience with science aircraft that have provided the agency a wealth of knowledge for operating UAS in the NAS. Combining existing operational data from the SMD's flight experience with experience from ARMD programs such as Airspace Systems and Aviation Safety will help ensure the success of the Integrated Systems Research Program.

ARMD Airspace Systems Program (ASP)

ASP addresses the fundamental air traffic management research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency, and flexibility of the NAS. Capabilities being developed include algorithms enabling separation assurance and collision avoidance of aircraft, and examination of roles and responsibilities between air traffic controllers, pilots, and airline operations as well as between humans and automation. The UAS integration in the NAS project will work closely with ASP to leverage those capabilities that can help enable UAS access. The UAS project will build off the ASP work by examining unique issues related to unmanned aircraft such as their unique missions, the speeds at which they fly, and conflict-free trajectory-based operations with an operator who is not onboard the craft.

ARMD Aviation Safety Program (AvSP)

AvSP pursues fundamental research that will result in the development of revolutionary and transformative safety assurance techniques for future aviation systems and operations within the public NAS. The program's contribution to aviation ranges from fundamental research aligned with known safety challenges, to working with partners to address the safety concerns created in new, complex systems. AvSP is developing a research plan to address a challenge of safely assuring the incorporation of complex technological capabilities and concepts of operation into the future NAS. Safety assurance techniques and verification and validation tools will be researched and developed for manufacturers and certifiers to use to assure flight-critical systems are safe in a rigorous and cost- and time-effective manner.

The planned technical approach will involve experimentation, testing, and evaluation of selected safety assurance tools and techniques applied to integrated system-level concepts. Concepts of interest will have identified safety assurance needs that will challenge or exceed the capabilities of existing methods of verification and validation. Given the goals of the UAS project, there will likely be UAS concepts of interest for the application of AvSP safety assurance tools and techniques. In particular, there may be attributes of UAS concepts that offer excellent opportunities for the evaluation of an overall safety assurance framework, as well as verification and validation tools for distributed, software-intensive systems with new human/automated system roles.

ARMD Integrated Systems Research Program (ISRP)
NASA's Integrated Systems research Program (ISRP) focuses on maturing and integrating NextGen technologies into major vehicle and operational systems and subsystems that will address critical national challenges. Using a system-level approach, NASA researchers explore, assess, and demonstrate the benefits of those technologies in a relevant operational environment. By focusing on technologies that have already proven their merit at the fundamental research level, this program will help transition them more quickly to the aviation community, as well as inform fundamental research needs. In addition, the program will focus on integrated system-level research of interest and importance to the aviation stakeholder community.

The UAS Integration in the NAS project is one of the projects within ISRP. This project began implementation in FY 11 and is slated to continue through FY 16. The goal of this project is to contribute capabilities that reduce technical barriers related to the safety and operational challenges associated with enabling routine UAS access to the NAS. It comprises four subprojects addressing key technology elements, including Human System Interface, Separation Assurance, Communication, and Certification, and a fifth subproject for Integrated Test and Evaluation.

Science Mission Directorate (SMD)
SMD has the only NASA mission requirement for accessing the national airspace with UAS. SMD flies UAS to satisfy requirements gathered from the science community that are best addressed with unique UAS capabilities. Global Hawk, IKHANA, and SIERRA are NASA owned and operated UAS that SMD currently supports and uses for its missions. In the past three years, SMD has flown two major Global Hawk missions to study pollution transport, hurricane intensification, and conduct satellite calibration and validation. The IKHANA flew several forest fire missions in the western United States, and SIERRA flew a sea-ice characterization mission out of Norway. Over the next five years, SMD will be flying two Earth Venture-1 missions with the Global Hawk to study more hurricane phenomenon and tropical radiation. Other activities include two SIERRA missions and an Arctic mission with the IKHANA. SMD also supports a full-time staff position with the FAA UAS Program Office to assist with COA development and provide UAS expertise to the FAA.

Primary Challenges and Objectives
NASA's upcoming challenges and objectives largely relate to its investment in the UAS integration in the NAS project. However, restricted operating environments for UAS have a large impact on missions for the science community. Using restricted airspace and operating under a COA impedes operational planning and potentially other mission objectives.

The vision of UAS integration in the NAS is a global transportation system that allows routine access for all classes of UAS. The ISRP UAS project goal is to use integrated system-level tests in a relevant environment to reduce technical barriers related to the safety and operational challenges of UAS NAS access, and to work with key stakeholders to define necessary products to help enable UAS access. This will be accomplished in two phases and in close coordination with the FAA, DOD, DHS, and industry. Phase One will take place the first two years of the project, and Phase Two will take place the following three years. The Phase One and Phase Two technical objectives are:

Phase One

- Develop a gap analysis between current SOA and NextGen ConOps
- Validate the key technical areas identified by this project
- Initial modeling, simulation, and flight testing
- Complete subproject Phase One deliverables (spectrum requirements, comparative analysis of certification methodologies, etc.) and continue Phase Two preparation (infrastructure, tools, etc.)

Phase Two

- Provide regulators with a methodology for developing airworthiness requirements for UAS, and data to support development of certifications standards and regulatory guidance
- Provide systems-level, integrated testing of concepts and/or capabilities that address barriers to routine access to the NAS. Through simulation and flight testing, address issues including separation assurance, communications requirements, and human-systems integration in operationally relevant environments

Scope of Involvement and Investment in UAS

NASA provides investments to UAS integration into the NAS through its extensive R&D activities and use of test facilities and aircraft. NASA's R&D investments include the four technical areas in the UAS in the NAS project:

- Separation Assurance
- Human Systems Integration
- Communications
- Certification

NASA also has a full range of assets to support the objectives that are necessary for implementing UAS into the NAS, including:

- Large UAS – Aircraft such as Global Hawks and Predator-B (IKHANA) represent UAS employed by several public agencies seeking routine access to the NAS. Both aircraft will not only directly support NASA's UAS integration in the NAS project, but will also support Science Mission Directorate objectives.
- Small UAS – NASA has several small UAS, such as the DROID, that are inexpensive to operate and will be used in various ways to support testing for many different UAS integration goals.
- Surrogates – Surrogate aircraft are unique because of their remote operation capability coupled with a safety feature of having an actual pilot on board the aircraft.
- Piloted Aircraft – A wide array of piloted aircraft can be used to test many different aspects of UAS integration in the NAS. NASA's piloted aircraft have capabilities that cover all size and speed spectrums.

- Simulation Labs – Simulation labs designed to simulate aircraft, airspace, and safety scenarios are used across NASA. These labs will be integrated to provide a Live Virtual Constructive (LVC) distributed flight-test environment that will play a crucial role in integrating UAS into the NAS.
- Other – NASA has other projects that test and fly UAS-relevant technologies. Aircraft such as the Boeing X-48B are operated by NASA to test new aircraft technologies on a UAS. UAS can be an important player in developing new advanced vehicle concepts for NASA's environmental aviation investments.

NASA is a member of several committees with objectives that relate to UAS integration in the NAS, including the UAS Executive Committee, the recently formed UAS Aviation Rulemaking Committee, Small UAS Aviation Rulemaking Committee (now concluded), and the NextGen UAS RD&D Executive, Planning and Technical Committees.

Envisioned Role in Interagency R&D

NASA has worked closely with the FAA for many years to operate UAS. NASA's current portfolio and assets are strategically operated to make NASA a key contributor to address routine UAS access into the NAS. The agency has leadership devoted to many aeronautics and UAS-related committees, a strong role in national scientific research, and a technical community that is devoted to integrating UAS in the NAS. NASA is prepared to work closely with all NextGen partner agencies to provide the necessary input and appropriate resources to develop and take a key implementation role in a strong NextGen UAS RD&D Roadmap

.

Appendix B

Summary of Critical Research and Development Challenges

This appendix presents a set of tables summarizing the information presented in Chapter 3. One table appears for each category of challenges (Communications, Airspace Operations, Unmanned Aircraft, and Human Systems Integration) describing the challenges, assumptions, R&D investors, ongoing and planned R&D, and anticipated goals and dates. Where applicable, the tables also present the notes from Chapter 3 associated with each challenge.

1. COMMUNICATIONS

	1.1 Impact of UAS operations on NextGen communication systems	1.2 Ensure availability of UAS control frequency spectrum	1.3 Develop and validate UAS control communication system performance requirements	1.4 Ensure security of safety critical communications with civil UAS	1.5 Design and develop UAS control datalink for allocated UAS frequency spectrum bands
Challenge	Characterize the capacity and performance impact of UAS operations on Air Traffic Control (ATC) communications system. Identify the modifications needed to NextGen communications systems.	Civil UAS require protected safety frequency spectrum for control communications; no such spectrum allocations currently exist. Detailed technical analyses and compatibility studies are required to identify and obtain international allocations.	Based on communications policy and procedures, communications architectures and safety considerations to be established; develop and validate detailed UAS control communications technical performance requirements.	Communications infrastructure between FAA, UAS operator and UAS needs to be secure. Develop and validate techniques and methods to ensure communications system security	Develop and validate hardware and standards for UAS control communications operating in allocated UAS spectrum
Assumptions	The current and planned ATC communications systems are not designed to account for the integration of UAS.	DOD will utilize their existing spectrum for control communications	There will be an initial set of policy, architecture and safety requirements; these will evolve. An iterative process is required to develop final communications technical performance requirements.	UAS systems require higher level of security than piloted systems	UAS specific spectrum allocation is made at WRC 2012
R&D Investors	FAA, NASA	NASA, FAA, DOD	NASA, FAA	NASA, FAA, DOD, DOT VOLPE	NASA
Ongoing/Planned R&D	UAS NextGen Demos 3 and 4, FAA NEO, NASA-UAS in the NAS project	NASA UAS in the NAS project, FAA Spectrum Office	UAS in the NAS project, FAA-ATO, FAA-AVS	UAS in the NAS, FAA (Data Comm, NextGen Voice System)	NASA UAS in the NAS
Gaps	Inadequate traffic forecast models for UAS; no plans to modify NextGen communications systems for UAS	None	Policy, architecture selection, and safety and hazard analysis needs to be done sooner than currently planned.	Potential gap on ATC links	No known gaps
Anticipated Goals/Dates	*Goal 1:* Complete characterization of capacity and performance impact of UAS on ATC communications systems; 2016 *Goal 2:* The demonstration of an integrated terrestrial voice communications network that includes UAS; 2012	*Goal 1* : Allocation of two terrestrial bands, by World Radio Communications (WRC) Conference, 2012 *Goal 2:* Allocation of satellite communications bands, by World Radio Communications (WRC) Conference, 2016	*Goal 1:* Complete large scale simulations of initial performance requirements, 2014 *Goal 2:* Complete flight testing of initial performance requirements , 2014 *Goal 3:* Verify and validate final performance requirements, 2016	*Goal 1:* Vulnerability analysis of UAS safety critical communications, 2012 *Goal 2:* Develop and validate technologies to mitigate vulnerabilities, 2015	*Goal 1:* Develop and validate UAS control link prototype *Goal 2:* Establish UAS control link national/international standards

2. AIRSPACE OPERATIONS						
	2.1 Develop Integrated Separation Concepts	**2.2 Develop Airspace Integration Safety Case/Assessment**	**2.3 Develop Sense and Avoid (SAA) Sensors and Fusion**	**2.4 Develop Separation Algorithms**	**2.5 Assess Availability/Quality of Surveillance Data**	**2.6 Develop Safe and Efficient Terminal Airspace/Surface Operations**
Challenge	The unmanned aircraft Collision Avoidance (CA), Self-Separation (SS) and Separation Assurance (SA) functions overlap and interact and therefore need to be integrated in a systematic manner. This requires the evaluation of the performance of different functional allocations for SA/SS/CA, the evaluation of the performance of different human/machine roles and responsibilities, and the integration of the separation assurance, self-separation and collision avoidance functions.	Develop a rigorous, analytical methodology for substantiating the safety of UAS operations in the NAS. This requires understanding of the risks and failure modes of SA/SS/CA integration, the performance of human/machine roles and responsibilities and the integration of separation assurance, self-separation and collision avoidance functions.	Safe operation will likely be achieved through data obtained from a variety of sources including on-board, off-board and cooperative sensors. Developing and evaluating sensors and sensor data fusion algorithms and approaches will be key to achieving the integrity required.	As the key to safe, efficient and "expected" behavior in the airspace, the maneuvering algorithms are a critical component of airspace operations. Therefore, Separation Assurance (SA), Self-Separation (SS) and Collision Avoidance (CA) algorithms must be developed. Algorithms must be developed to minimize impact to operations while maintaining safety. These algorithms and the analyses thereof will inform many policy decisions (algorithm-based or requirements-based standards)—one as opposed to many. While avoiding other aircraft is the critical function, future safety concerns will include weather, wake vortices, terrain, etc.	NextGen aircraft will have a variety of available surveillance data sources and performance of the separation algorithms depends on the quality of the data. The different levels of data availability/reliability/integrity/continuity/accuracy (air v. ground, weather, ATC v. other users) must be assessed. The availability and impact of intent/trajectory prediction information on operations performance must also be assessed. While knowledge of other aircraft is the critical item, future concerns will include weather, wake vortices, etc.	Complete airspace operations include operations in a terminal/surface environment where efficiency as well as safety is paramount. Operations in this complex and restrictive environment create additional challenges in guidance and navigation, integrity management, responsiveness to ATC commands, sensors and collision avoidance.
Assumptions	Surveillance data for SA will exist in the appropriate timeframe. Validated requirements for SA, SS and CA will be available in an appropriate timeframe.	System, sub-system, and component-level technologies are understood and documented sufficiently to support safety case development.	Validated requirements for SS and CA will be available in an appropriate timeframe.			
R&D Investors	FAA, NASA, DOD	FAA, NASA, DOD	FAA, DOD	FAA, NASA, DOD	FAA, NASA, DOD	FAA, NASA, DOD
Ongoing/ Planned R&D	Current and planned activities, if executed, provide strong coverage	Current and planned activities, if executed, provide strong coverage	Current and planned activities, if executed, provide strong coverage	Current and planned activities, if executed, provide strong coverage	Current and planned activities, if executed, provide strong coverage	Current and planned activities, if executed, provide strong coverage
Anticipated Goals/Dates	*Goal 1:* Develop pilot, ATC, and automation roles and responsibilities concepts, 2012 *Goal 2:* Develop integrated, autonomous and human-in-the-loop sense and avoid (SS & CA) algorithms, 2012 *Goal 3:* Develop integrated, autonomous and human-in-the-loop separation assurance (SA) algorithms and integration with SS & CA, 2015	*Goal 1* : Develop safety case methodology through analysis and specific assessments, 2012 *Goal 2* : Develop Target Level of Safety criteria for UAS Airspace Operations, 2012 *Goal 3:* Provide performance data and analyses to support safety case development, 2014+	*Goal 1:* Demonstrate mosaic of primary and secondary radars on CDTI display; 2011 Goal 2: Flight demonstrate fusion of EO/IR, radar, TCAS and ADS-B; 2012, SWIR/radar; 2013	*Goal 1:* Flight demonstrate SS & CA algorithms, multiple sensors and intruders, 2011 *Goal 2:* Evaluate risk-based SS algorithm and policy issues, 2012 *Goal 3:* Flight demonstrate SA algorithms, criteria-based separation, 2015	*Goal 1:* Establish surveillance data concepts, separation volume definition and roles and responsibilities, 2012 *Goal 2:* Assess performance of various self-separation concepts as a function of surveillance data configurations, 2012 *Goal 3:* Assess performance of various separation assurance concepts as a function of surveillance data configurations, 2015 *Goal 4:* Assess benefits of availability of intent information, 2018	*Goal 1:* Evaluate impact of multiple UAS in terminal airspace controller workload, 2012 *Goal 2* : Evaluate surveillance data sources in terminal environment, 2014 *Goal 3:* Ground demonstration of autonomous airfield navigation and ATC interaction, 2018
Notes	The roles and responsibilities evaluation in this challenge will be worked in conjunction with the Human Factors Roles and Responsibilities challenge.	1. A complete safety case would cover much more than just the airspace operations components. 2. Providing supporting data and analyses is an ongoing process—output from most tech development activities 3. Gap: The "official" airspace model against which UAS will be evaluated does not exist. That might need to be captured as an activity or set of activities here. 4. The roles and responsibilities evaluation in this challenge will be worked in conjunction with the Human Factors Roles and Responsibilities challenge.	Not sure what exactly FAA/TCRG sensor fusion activity is doing and whether or not it is covered by the goals as stated.	Gao: The "official" airspace model against which separation algorithms will be evaluated does not exist.		

3. UNMANNED AIRCRAFT				
	3.1 State Awareness and Real Time Mission Management	**3.2 Airframe Certification**	**3.3 Precise Location And Navigation**	**3.4 UAS Avionics and Control Systems Certification**
Challenge	UAS change trajectories many times during flight, negotiating these real time is labor intensive and inefficient. Furthermore without a pilot on board, the UAS will have to generate awareness of the aircraft state during operations. Research in this area provides aircraft systems state awareness and thereby enable efficient and timely trajectory negotiations at multiple levels, e.g., aircraft, system-of-systems and NAS levels. The technology could also be critical for certifying aircraft safety in the event of component failures for operations in the NAS.	Enable the rapid and affordable airframe certification for all types of UAS through increase emphasis on structural analysis and reduction in airframe testing. The existing basis of certification does not cover the new and novel materials and manufacturing processes being used in the manufacturing of UAS. As these methods and materials continue to evolve, research is needed make an airworthiness determination and continue to ensure airworthiness over the life of the aircraft.	UAS are being developed with a strong dependence upon GPS as a source for Guidance, Navigation, and Control (GN&C) information, so much so that a single failure mode situation is potentially present. Without a human pilot on board to provide a means of back-up, critical situation awareness would be lost, and the platform could put human life and infrastructure at risk.	Existing software verification and validation tools and techniques are inadequate to address the complexity of emerging avionics and control software suites. As such, new tools and techniques are necessary to support UAS development to ensure the safety and reliability of these systems.
Assumptions	In general a common architecture needs to be developed to allow for technology development. This architecture is more than just aircraft it includes ground system. We assume that a standard functional architecture will be developed for NextGen.			
R&D Investors	DOD-Air Force/Navy, NASA	DOD-Air Force	DOD-Air Force	DOD-Air Force, NASA
Ongoing/Planned R&D	Current and planned activities, if executed, provide fair coverage	Current and planned activities, if executed, provide fair coverage		
Anticipated Goals/Dates	*Goal 1:* Demonstrate real-time state awareness for unmanned space access, 2014 *Goal 2:* Demonstrate real-time trajectory negotiation based on state awareness in NAS, 2020	*Goal 1:* Certified an airframe by analysis verified by test, 2020 *Goal 2:* Develop certification standards for advanced materials and structural design, 2020 *Goal 3:* Continued airworthiness through on-board health monitoring, 2030	Note: Much of this research is not publically releasable and will not be discussed in this document.	*Goal 1* : Demonstrate software certification artifacts using analysis and reduce testing, 2018 *Goal 2:* Demonstrate methodology for System of Systems interaction modeling and certification, 2025 *Goal 3:* Develop methodology for shared redundancy certification, 2030

4. HUMAN SYSTEMS INTEGRATION								
	4.1 Display of Traffic/Airspace Information	**4.2 Effective Human-Automation Interaction**	**4.3 Pilot-Centric GCS**	**4.4 Definition of Roles and Responsibilities**	**4.5 Predictability and Contingency Management**	**4.6 System-Level Issues**	**4.7 NextGen Airspace Users and Providers – Qualification and Training**	**4.8 Support for Future/Enhance Capability of UAS**
Challenge	Develop display of traffic/airspace information. This information would include traffic information (knowledge of equipage); airspace information (weather, etc.); separation assurance interface (sense and avoid); visualization tools (weather, wind, traffic, air routes, frequency); and displays/tools for enable and monitoring of GCS NextGen trajectory- based operations for dynamic re-planning.	Provide needed data to enable effective human-automation interaction for UAS in the NAS. Issues of concern within this area include automation implementation (trust, predictability, understanding, control loops—manned vs. unmanned); levels of automation (mode awareness, transparency, bias/trust); and human-automation interface (SA, vigilance decrements, skill degradation).	Prototype and empirically validate pilot-centric GCS operator interface. Sub-issues within this challenge include minimum equipment list (display, controls, etc.); identify and reconcile the delta between manned and unmanned; sensory deficit and remediation; address communication latency in design; handoffs (within a single GCS and between GCS); and configuration/facility (sterile cockpit).	Understand and design for NextGen roles and responsibilities. Sub-issues within this challenge include changing roles and responsibilities for NextGen communication flow among UAS team, ATC, and flight dispatchers; function allocation (operators, ATC, automation, human); and roles and responsibilities for mission management in contingencies; and centralized/distributed decision making. This challenge is directly related to Airspace Operations challenges (Develop Integrated Separation Concepts) and the section on Develop Airspace Integration Safety Case/Assessment.	Integrate effective contingency management system with GCS. Sub-issues within this challenge area include: recognition of new system faults and proper response in NextGen; identifying appropriate predictability requirements (aircraft, ATC, pilots of manned aircraft); lost/intermittent link status/health; and lost communications to ATC.	Understand HSI aspects of system-level analyses of UAS/NextGen environment. Sub-issues within this challenge include NAS-wide human-performance requirements with toolset of test-bed and metrics; information requirements and flow among UAS, ATC; and ATC compliance equivalency (crew and overall system response).	Formulate NextGen-specific qualification and training requirements for users and providers. Sub-issues within this challenge area include crew/ATC skill set; training, certification; and qualification.	Support future and enhanced capability for UAS. Sub-issues within this challenge area include net-centric operations, cooperative control/swarming, and multiple UAS control by a single control system.
Assumptions	No additional Assumptions	No additional Assumptions	No additional Assumptions	No additional Assumptions	No additional Assumptions		No additional Assumptions	No additional Assumptions
R&D Investors	NASA, DOD-Air Force, FAA	NASA, DOD-Air Force	NASA, DOD-Air Force, FAA	NASA, DOD-Air Force	NASA, DOD-Air Force		DOD-Air Force	DOD-Air Force
Ongoing/Planned R&D	Current and planned activities, if executed, will partially address this challenge.	Current and planned activities, if executed, are sufficient to address this challenge.	Current and planned activities, if executed, are sufficient to address this challenge.	Current and planned activities, if executed, will partially address this challenge.	Current and planned activities, if executed, will partially address this challenge.		Current and planned activities, if executed, will partially address this challenge.	Current and planned activities, if executed, are sufficient to address this challenge.
Anticipated Goals/Dates	*Goal 1:* Integrate NextGen-representative technologies for traffic, weather, and terrain avoidance into a Ground Control Station (GCS), 2017.	*Goal 1* : Define task allocation for human automation for all phases of flight, 2014. *Goal 2:* Define appropriate levels of automation, transparency, maintained operator engagement and flexible, intuitive control, 2018.	*Goal 1:* Demonstrate GCS that meets requirements to safely operate a specific UAS in the NAS at acceptable pilot workload levels, 2017.	*Goal 1:* Inform and demonstrate the feasibility and acceptability of NextGen roles and responsibilities, 2017.	*Goal 1:* Develop an integrated Caution Warning Advisory (CWA) for normal and contingency operations, 2017.		*Goal 1:* Inform minimum set of standards for all users and providers regarding operation in the NAS, 2016.	*Goal 1:* Demonstrate increasing multiple aircraft control capability for benign operations (transit) by a single operator, 2014.

Appendix C

List of Contributors

NextGen UAS R&D Executive Committee

FAA
Vicki Cox, Senior Vice President, NextGen

DHS
John Stanton, Executive Director, National Air Security Operations, Office of Air and Marine Customs and Border Protection

DOC
Robbie Hood, NOAA, UAS Program Director

DOD
Steve Pennington, Director of Bases, Ranges, and Airspace, and Acting Executive Director for the DOD Policy Board on Federal Aviation

NASA
Dr. Jaiwon Shin, Associate Administrator, Aeronautics Research Mission Directorate

NextGen UAS R&D Executive Planning Committee

DHS
Dr. John Appleby, Program Manager, Borders & Maritime Security Division, Homeland Security Advanced Research Projects Agency, Science & Technology Directorate

DOC
Philip Kenul, NOAA, UAS Acting Deputy Program Director

DOD
Jack Blackhurst, Director,
Human Effectiveness Directorate, AFRL

Dallas Brooks, Airspace Integration IPT Lead, OUSD(AT&L)/A/S&TS-UW

FAA
Dennis Roberts, Director, Airspace Services, Mission Support Services

Paul Fontaine, Manager, Technology Development and Prototyping Group, NextGen

Les Smith, Manager, Flight Standards Service, Flight Technologies and Procedures Division

NASA
Dr. John A. Cavolowsky, Director,
Airspace Systems Program

Dr. Edgar G. Waggoner, Director,
Integrated Systems Research Program

NextGen UAS R&D Technical Track Leads

DOD
Dr. Daniel Thompson, Senior Technical Advisor (AFRL/RBC), Air Vehicles Directorate, AFRL

Dr. Mark Draper, Principal Engineering Research Psychologist, AFRL

Robert Smith, Autonomous System Lead, Aerospace Systems Directorate, AFRL

NASA
Dr. Jim Griner, Project Engineer, UAS Integration in the NAS

Dr. Robert J. Shively, Human Systems Integration Group Leader, Aeroflight Dynamics Directorate, Aviation and Missile Research and Engineering Center (AMRDEC)

FAA
Wesley Wright, Division Manager, NextGen En Route/Oceanic Portfolio

JPDO

Dr. Karlin Toner, Director
Michael Dudley, Deputy Director

Dr. Catherine Harrison, AFRL Principal Research Liaison, JPDO UAS Program Manager

Appendix D

List of Acronyms

4DT	Four-dimensional Trajectory
ACTD	Advanced Concept Technology Demonstration
ADS-B	Automatic Dependant Surveillance-Broadcast
AFRL	Air Force Research Laboratory
AFSOC	Air Force Special Operations Command
ARMD	Aeronautics Research Mission Directorate
ASP	Airspace Systems Program
AT&L	Acquisition, Technology and Logistics
ATC	Air Traffic Control
ATM	Air Traffic Management
ATO	Air Traffic Organization
AVS	Aviation Safety Organization
AvSP	Aviation Safety Program
BAMS	Broad Area Maritime Surveillance
C2	Command and Control
CA	Collision Avoidance
CBP-OAM	Customs and Border Protection Office of Air and Marine
CDTI	Cockpit Display of Traffic Information
CENTCOM	Central Command
CFR	Code of Federal Regulations
COA	Certificate of Waiver or Authorization
COCOM	Combatant Command
ConOps	Concept of Operations
DHS	Department of Homeland security
DNRS	Digitally Networked Radio System
DOC	Department of Commerce
DOD	Department of Defense
DSPO	Defense Standardization Program Office
EO	Electro-optical
EU	European Union
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FFRDC	Federally Funded Research and Development Center
FOL	Forward Operating Location
GBSAA	Ground-based Sense and Avoid
GCAS	Ground Collision Avoidance System
GCS	Ground Control Station
GH	Global Hawk
GPS	Global Positioning System

HFM	Human Factors and Medicine
HIS	Human Systems Integration
HITL	Human-in-the-Loop
HSI	Human System Integration
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IR	Infrared
ISR	Intelligence, Surveillance and Reconnaissance
ISRP	Integrated Systems Research Program
ITA	International Trade Administration
JOCA	Jointly Optimal Conflict Avoidance
JPDO	Joint Planning and Development Office
LVS	Live Virtual Constructive
MAS	Manufacturing and Services
MD	Mission Development
MDA	Maritime Domain Awareness
MIT	Massachusetts Institute of Technology
MOMU	Multi-operator, Multi-UAS
MTS-B	Multi-spectral Targeting System–B
MUM	Manned-Unmanned
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NCO	Net Centric Operations
NEI	National Export Initiative
NEO	Network Enabled Operations
NextGen	Next Generation Air Transportation System
NITRD	Networking and Information Technology Research and Development
NOAA	National Oceanic and Atmospheric Administration
NORTHCOM	Northern Command
NRC	Nuclear Regulatory Commission
NSF	National Science Foundation
NVS	NAS Voice Switch
OC	Operating Center
OGA	Other Government Agency
OH	Ohio
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
OSTP	White House Office of Science and Technology Policy
OUSD	Office of the Undersecretary of Defense
PACOM	Pacific Command
PBFA	Policy Board on Federal Aviation
PNT	Positioning, Navigation and Timing
POC	Point of Contact
R&D	Research and Development

RD&D	Research, Development and Demonstration
RMP	Research Management Plan
RVSM	Reduced Vertical Separation Minimum
S&T	Science and Technology
SA	Separation Assurance
SAA	Sense and Avoid
SAC-EC	Special Airworthiness Certificate - Experimental Category
SC	Special Committee
SMD	Science Mission Directorate
SOF	Special Operations Forces
SPA	Special Purpose Aircraft
SRMD	Safety Risk Management Document
SS	Self-separation
STANAG	Standardization Agreement
SUAS	Small Unmanned Aircraft System/Systems
SWIM	System Wide Information Management
SWIR	Short-wave Infrared
TBO	Trajectory Based Operations
TCAS	Traffic Collision Avoidance System
TCRG	Technical Community Requirements Group
TRL	Technology Readiness Level
U.S.	United States
UA	Unmanned Aircraft
UAE	United Arab Emirates
UAPO	Unmanned Aircraft Program Office
UAS	Unmanned Aircraft System/Systems
UAS ExCom	UAS Executive Committee
USAF	United States Air Force
USCG	United States Coast Guard
USSOCOM	United States Special Operations Command
VFR	Visual Flight Rules
VOIP	Voice Over Internet Protocol
VSCS	Vigilant Spirit Control Station
WAS	Wide-area Surveillance
WRC	World Radio Communications
WWII	World War Two