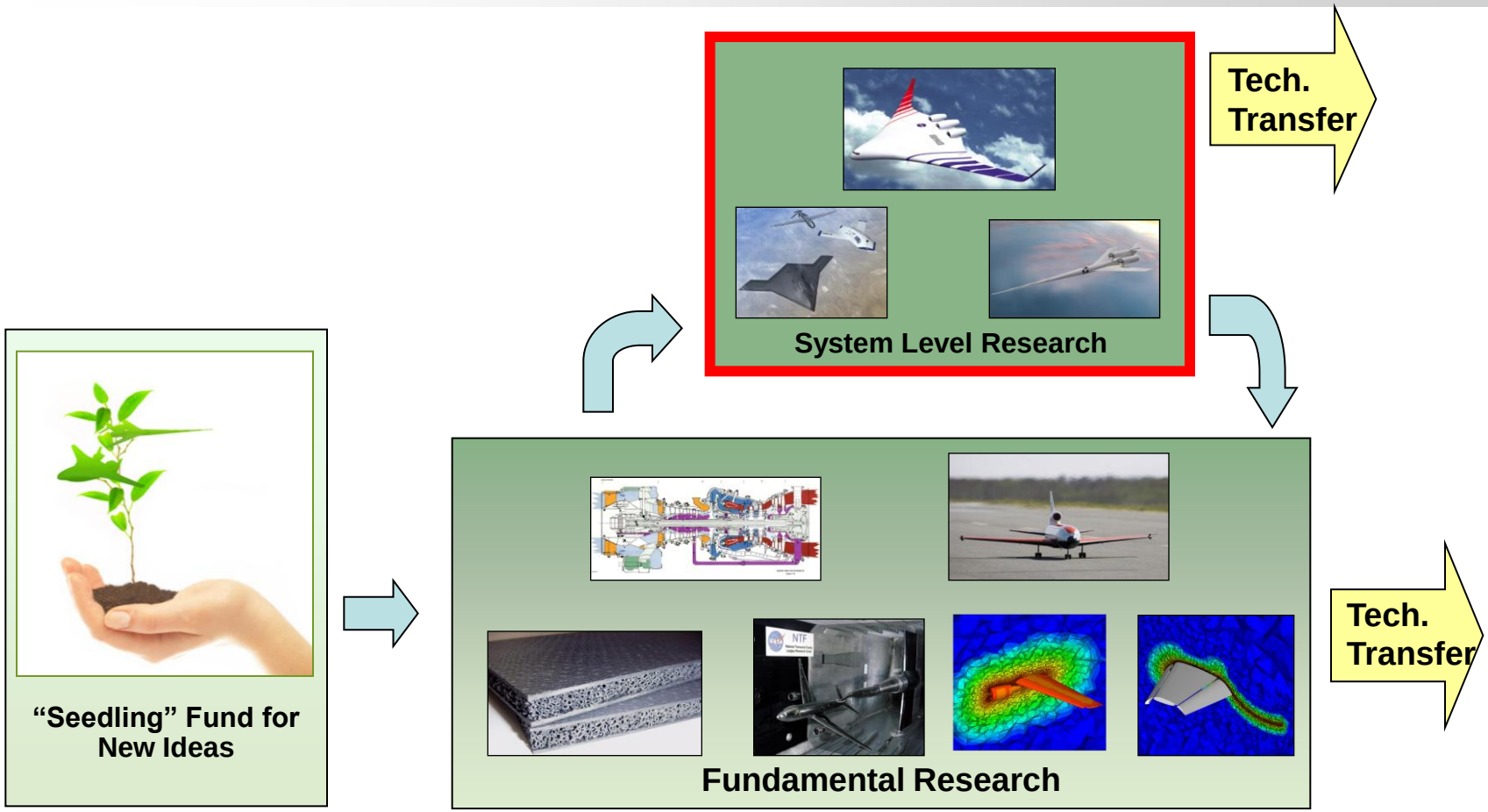
Aeronautics Research Mission Directorate Integrated Systems Research Program (ISRP) and UAS Integration in the NAS Project

Presented by: Ms. Jean Wolfe
Director (Acting), Integrated Systems Research Program

Meeting of Experts on NASA's Unmanned Aircraft System (UAS) Integration in the National Airspace Systems (NAS) Project

Aeronautics and Space Engineering Board
National Research Council
August 5, 2010

NASA Aeronautics Investment Strategy



Enabling "Game Changing" concepts and technologies from advancing fundamental research ultimately to understand the feasibility of advanced systems

NASA Aeronautics Portfolio in FY2010

Fundamental Aeronautics Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

Integrated Systems Research Program

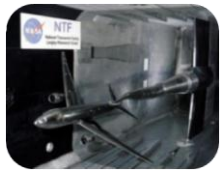
Conduct research at an integrated system-level on promising concepts and technologies and explore/assess/demonstrate the benefits in a relevant environment

Airspace Systems Program

Directly address the fundamental ATM 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.

Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologiesto improve the intrinsic safety attributes of current and future aircraft.



Aeronautics Test Program

Preserve and promote the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.

ISRP Goal and Characteristics

Integrated Systems Research Program (ISRP):
Research and technology (R&T) program that will conduct research at an integrated system-level on promising concepts and technologies and explore, assess, or demonstrate the benefits in a relevant environment

Criteria for selection of projects for Integrated Systems Research:

- Technology has attained enough maturity in the foundational research program that they merit more in-depth evaluation at an integrated system level in a relevant environment
- Technologies which systems analysis indicates have the most potential for contributing to the simultaneous attainment of goals
- Technologies identified through stakeholder input as having potential for simultaneous attainment of goals
- Research not being done by other government agencies and appropriate for NASA to conduct
- Budget augmentation

Integrated Systems Research Program Overview

Program Goal:
Conduct research at an integrated system-level on promising concepts and technologies and explore, assess, or demonstrate the benefits in a relevant environment

Environmentally Responsible Aviation (ERA) Project

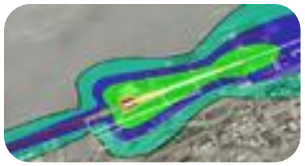
Explore and assess new vehicle concepts and enabling technologies through system-level experimentation to *simultaneously* reduce fuel burn, noise, and emissions

Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

Contribute capabilities that reduce technical barriers related to the safety and operational challenges associated with enabling routine UAS access to the NAS

Innovative Concepts for Green Aviation (ICGA) Project

Spur innovation by offering research opportunities tothe broader aeronautics community through peer-reviewed proposals, with a focus on making aviation more eco-friendly. Establish incentive prizes similar to the Centennial Challenges and sponsor innovation demonstrations of selected technologies that show promise of reducing aviation's impact on the environment



FY 2011 Budget Submit

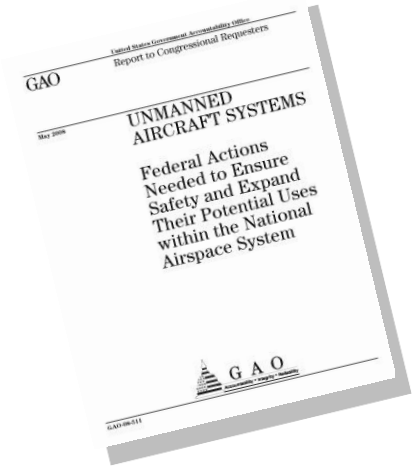
($ Millions)	FY 2009 Actual 1/	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Aeronautics Total	**650.0**	**507.0**	**579.6**	**584.7**	**590.4**	**595.1**	**600.3**
Aviation Safety	**89.3**	**75.0**	**79.3**	**78.9**	**81.2**	**81.9**	**82.7**
Airspace Systems	**121.5**	**80.0**	**82.2**	**82.9**	**85.9**	**86.6**	**87.4**
Fundamental Aeronautics	**307.6**	**220.0**	**228.5**	**231.4**	**236.0**	**241.8**	**244.6**
Aeronautics Test	**131.6**	**72.0**	**76.4**	**76.4**	**75.6**	**77.4**	**78.2**
Integrated Systems Research	**0.0**	**60.0**	**113.1**	**115.1**	**111.7**	**107.4**	**107.4**
Environmentally Responsible Aviation	0.0	60.0	73.1	75.1	71.7	67.4	67.4
Innovative Concepts for Green Aviation	0.0	0.0	10.0	10.0	10.0	10.0	10.0
UAS Integration into the NAS	0.0	0.0	30.0	30.0	30.0	30.0	30.0

1/ FY 2009 shows the July Operating Plan including the American Recovery and Reinvestment Act.
2/ FY 2010 shows the Consolidated Appropriation Act, 2010 (PL 111-117) without the Administrative transfers.

Rationale for UAS NAS Integration Project

- The need to fly UAS in the NAS is of increasing urgency to perform missions of vital importance to national security and defense, emergency management, and science (DOD, DHS, FEMA, NASA, DOC, NOAA)
- UAS are unable to routinely access the airspace system today
- No regulations for UAS exist – aviation regulations built upon condition of pilot being onboard vehicles
- Need technologies and procedures to enable seamless operation and integration of UAS in the NAS

Alignment


United States Government Accountability Office
Report to Congressional Requesters

GAO

May 2006

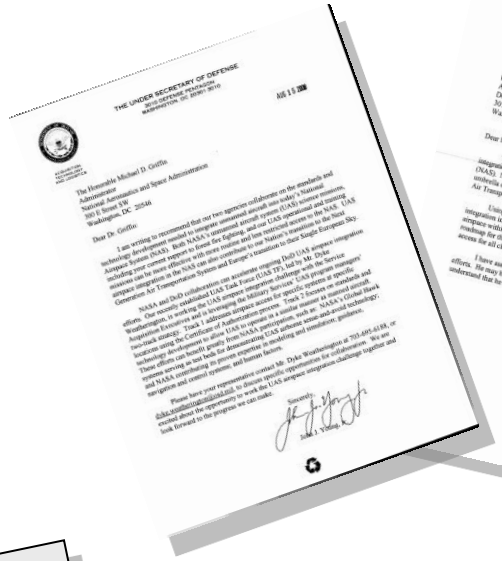
UNMANNED AIRCRAFT SYSTEMS

Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System

GAO

GAO-06-511

GAO Report


THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

AUG 11 2008

The Honorable Michael D. Griffin
Administrator
National Aeronautics and Space Administration
300 E Street SW
Washington, DC 20546

Dear Dr. Griffin:

I am writing to recommend that our two agencies collaborate on the standards and technology development needed to integrate unmanned aircraft into today's National Airspace System (NAS). Both NASA's unmanned aircraft research (UAS) science mission, including your current request to fund five fighting, and our UAS operational requirements, offer opportunities to work more effectively with our Nation's transition to the Next Generation Air Transportation System and Europe's transition to their Single European Sky airspace integration initiatives.

NASA and DoD collaboration on systems engineering DoD UAS airspace integration efforts. The recently established UAS Task Force (UAS-TF), led by Mr. Dyke Weatherington, is working the UAS airspace integration challenge with the Service Acquisition Executives and is leveraging the Military Services' UAS program managers' two-track strategy. Track 1 addresses airspace access for specific UAS program requirements within the NAS over the next one to three years. The plan should include a roadmap for the technology and policy development required to achieve routine global access for all classes of UASs.

Using the JPDO as a forum, we would propose a national plan for UAS integration into the Next Generation Air Transportation System as well as achieve routine airspace within the NAS over the next one to three years. The plan should include a roadmap for the technology and policy development required to achieve routine global access for all classes of UASs.

Three efforts on Track 2 provide greater flexibility and leverage NASA's Global Hawk and NASA contributing to present expertise and human factors.

Please have your representative contact Mr. Dyke Weatherington at 703-695-6188, or dyke.weatherington@osd.mil, to discuss specific opportunities for collaboration. We are excited about the opportunity to work this UAS airspace integration challenge together and look forward to the progress we can make.

Sincerely,

John J. Young, Jr.

National Aeronautics and Space Administration
Office of the Administrator
Washington, DC 20546-0001

September 22, 2008

The Honorable John J. Young, Jr.
Under Secretary of Defense
Acquisition, Technology and Logistics
Department of Defense
3010 Defense Pentagon
Washington, DC 20301-3010

Dear Mr. Young:

Thank you for your letter dated August 15, 2008, concerning collaboration on the integration of unmanned aircraft systems (UAS) into the National Airspace System (NAS). NASA is fully supportive of this collaboration, particularly if it is under the umbrella of the Joint Planning and Development Office (JPDO) for the Next Generation Air Transportation System.

Using the JPDO as a forum, we would propose a national plan for UAS integration into the Next Generation Air Transportation System as well as achieve routine airspace within the NAS over the next one to three years. The plan should include a roadmap for the technology and policy development required to achieve routine global access for all classes of UASs.

I have assigned Mr. Jeffrey Bauer as our point of contact for UAS integration efforts. He may be contacted at (661) 276-2240 or at jeffrey.e.bauer@nasa.gov. I understand that he has already been in contact with Mr. Weatherington in this regard.

Sincerely,

Michael D. Griffin
Administrator

Under Secretary of Defense for Acquisition, Technology, and Logistics and

NASA Administrator Correspondence

NRC Report

– D10 Safe operation of unmanned aerial vehicles in the national airspace The use of UAVs for a variety of civil applications (e.g., farming, communications relays, border monitoring, power line and pipeline monitoring, and firefighting) will continue to increase. Flight operations of military UAVs in civil airspace is also expected to increase. To facilitate these operations, UAVs should be integrated into the air transportation system…

Decadal Survey

SEC. 1116. COOPERATIVE UNMANNED AERIAL VEHICLE ACTIVITIES.

The Administrator, in cooperation with the Administrator of NOAA and in coordination with other agencies that have existing civil capabilities, shall continue to utilize the capabilities of unmanned aerial vehicles as appropriate in support of NASA and interagency cooperative missions. The Administrator may enter into cooperative agreements with universities with unmanned aerial vehicle programs and related assets to conduct collaborative research and development activities, including development of appropriate applications of small unmanned aerial vehicle technologies and systems in remote areas.

Executive Branch Guidance

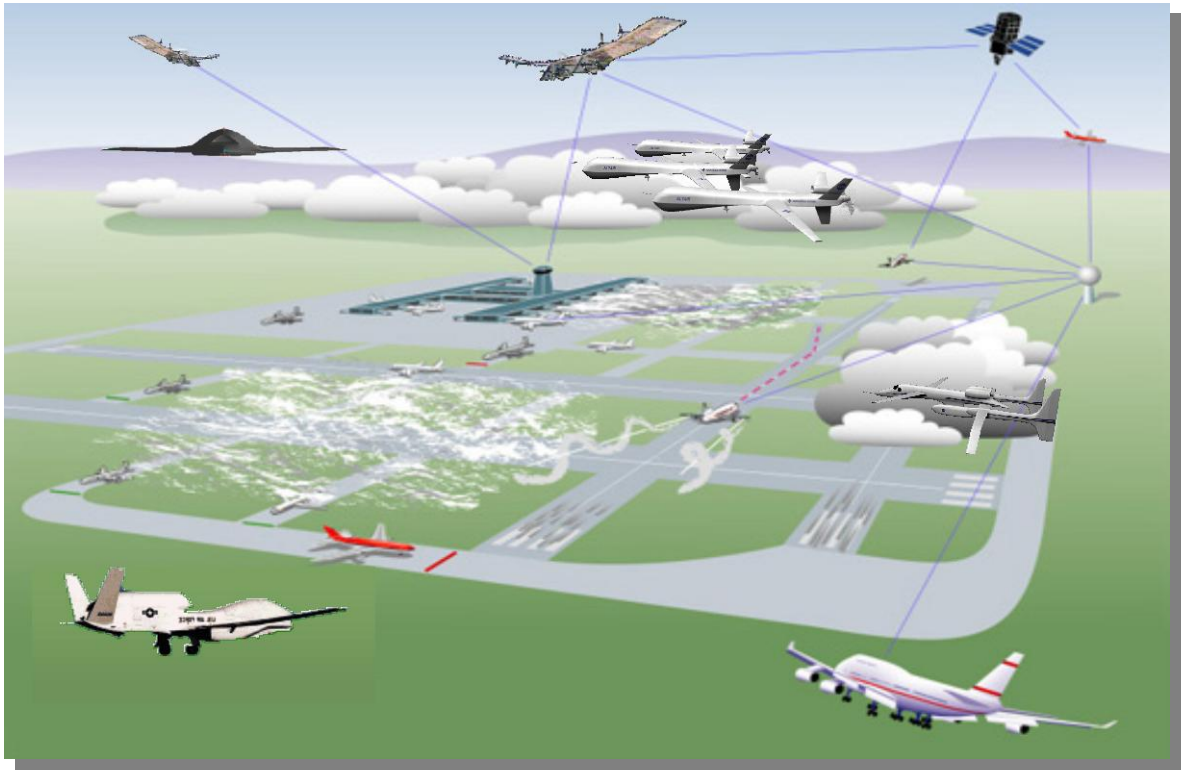
- Address operational and safety issues related to the integration of unmanned aircraft systems (UAS) into the national airspace
- Coordinate efforts with other UAS stakeholders in the DoD, DHS and FAA to avoid duplication and accommodate all user requirements

NASA Contributions to UAS Integration in the NAS

- Concept of Operations (ConOps) and Technology Roadmaps to enable focus for research and technology investments
- Simulations and field trials of technology developments designed to achieve safe separation of UAS in NextGen traffic densities
- Validated design guidelines and prototypes to improve safety and reliability
- Agreements with partners and stakeholders to effectively transition matured technology and inform investment readiness and implementation decisions for measurable system benefits

NASA

UAS Integration into the NAS Project



Presented by: Mr. Jeff Bauer
Project Planning Lead

Meeting of Experts on NASA's Unmanned Aircraft System (UAS) Integration in to the National Airspace Systems (NAS) Project

Aeronautics and Space Engineering Board
National Research Council
August 5, 2010

www.nasa.gov

Outline

- Problem Statement & Background
- Project Goals & Objectives
- Scope
- Approach
- Project Milestones
- Partnerships
- Resources & Acquisition Strategy

Problem Statement

- Requirements do not exist for routine UAS operations in the NAS
  - **Complicating Factors**
    - No one has defined success
      - ❑ **Lack of a broadly accepted plan for what needs to be done to enable access makes identifying and working solutions difficult**
    - Today's airspace system "Now Generation (NowGen)" versus Next Generation (NextGen)
      - ❑ **We don't want to solve the problem for today's environment only to have to solve it again when NextGen is implemented**
    - Public versus civil UAS operations
      - ❑ **Civil UAS operations require FAA certification and those requirements and/or guidance do not exist**
      - ❑ **Public agencies can self certify by supplying the FAA with an airworthiness statement**
    - UAS represent a wider performance regime than current aircraft
      - ❑ **Smaller, autonomous, pilot in-the-loop, pilot on-the-loop, extremely long endurance, very slow, etc.**
      - ❑ **Requirements for access will need to account and vary for each class**

Some of the Requirements for UAS in the NAS Access

- Ensuring separation assurance (sense and avoid – obstacles, weather, etc.)
- Ensuring adequate collision avoidance
- Ensuring robust and secure communications technologies
- Solving the constraints of frequency spectrum allocation
- Developing robust PAIs
- Developing ground control station standards
- Defining airworthiness and operational standards
- Defining pilot certifications requirements
- Developing certification standards for automated systems
- Defining appropriate level of safety through systematic safety analysis
- Developing certification standards for a wide range and/or type of UAS
- Developing integrated solutions for off-nominal operations
- Defining operational requirements for current and future missions sets
- Developing Ground Control Stations (GCSs) modifications for NAS compliance
- Defining display requirements for aircraft registration numbers
- Defining UAS lighting requirements
- Defining right-of-way procedures
- Developing surface operations procedures

What the UAS Community Needs from NASA

Joint Planning and Development Office (JPDO)

- Needs NASA to extend ATM research to address UAS integration in NextGen (algorithms for separation assurance and demonstrations (demos) of concepts and technologies).
- Needs NASA to work with JPDO and partners to develop a UAS ConOps (roadmap).

FAA (UAS Program Office & Technical [Tech] Center)

- UAS Program Office which has requested NASA help in addressing human factors issues related to pilot-aircraft interface
- FAA, along with RTCA-203 have requested NASA expertise on UAS communication issues related to UAS communication security risks/vulnerabilities, risk mitigation, architectures, latencies, etc.
- FAA has requested access to NASA UAS aircraft to support integrated testing

DoD

- Access to NASA flight platforms to assist with their technology development.

Standards Organizations

- Define and validate spectrum requirements, frequency models, and analyses for UAS communications at World Radio Conference (WRC).

UAS ExCom Senior Steering Group

- COA improvement support
- Roadmap support

What Have We Been Doing to Prepare for the Initiation of the Project?

- **Funding for short duration (1 yr) focused activities to accelerate project efforts**
- **American Recovery and Reinvestment Act (ARRA) Funding**
  - Developing a UAS NextGen ConOps
    - The ConOps will serve as input to the NextGen ConOps and assist the JPDO in meeting their 2012 milestone for incorporating UAS into their plans
    - The ConOps will influence the Integrated Work Plan (IWP)
  - Tools Development
    - Developing infrastructure to support the UAS NextGen ConOps validation primarily in the areas of simulation
- **FY10 In-Guide Funding**
  - Extend the tools development work begun with ARRA funds
  - Three focus areas:
    - Separation assurance and collision avoidance
    - Simulation and modeling
    - Systems Analysis to validate technical focus

Project Goals & Objectives

The goal of the UAS Integration in the NAS 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

This goal will be accomplished through a two-phased approach of system-level integration of key concepts, technologies and/or procedures, and demonstrations of integrated capabilities in an operationally relevant environment. Technical objectives include:

PHASE 1

- Validating the key technical areas identified by this project. System-level analyses, a State of the Art Analysis (SOAA), and a ConOps will identify the challenges and barriers preventing routine UAS access to the NAS.
- Developing a national roadmap and gap analysis identifying specific deliverables in the area of operations, procedures, and technologies that will impact future policy decisions.

PHASE 2

- 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 Pilot Aircraft Interfaces (PAIs) in operationally relevant environments.

Project Scope

- Demonstrate solutions in four specific technology disciplines, which will address operational and/or safety issues related UAS access to the NAS.
  - **Separation Assurance and/or Collision Avoidance**
  - **Pilot Aircraft Interface**
  - **Certification Requirements**
  - **Communications**

- Each discipline will transfer technologies to relevant stakeholders (including the FAA, DoD, standards organizations, and industry).

- The timeframe for impact will be 2015-2025.

- Support the UAS ExCom in developing a national roadmap/plan for Federal Public UAS in the NAS integration.

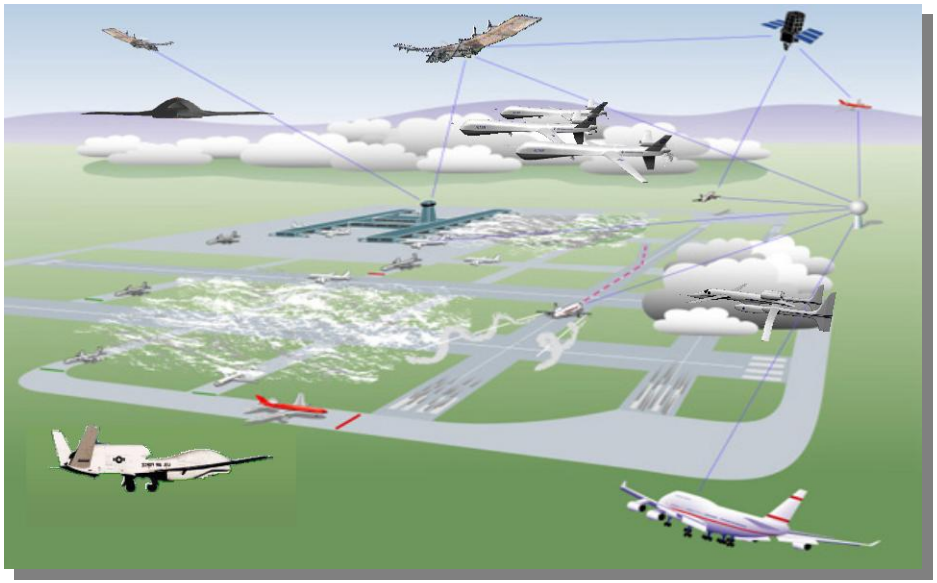
How We Determined the Project Focus

- Executive branch direction
- Listened to stakeholders
- Broad applicability
- Enables others to act
- Work align with NASA skills and expertise
- Demonstrated commitment by external community to utilize the deliverable
- Uniqueness (not duplicative work) and leverage
- Technical maturity (higher has priority over lower)

Technical Approach

- Project will consist of a 2-Phased Approach
- Phase 1 will focus on activities laying the foundation for the project
  - **Development of ConOps, systems analysis, state-of-the-art assessments, gap analysis**
  - **Development of a national roadmap for UAS access into the NAS**
  - **Activities will either validate NASA investments or suggest modifications to research portfolio**
- Phase 2 will focus on maturing research concepts/capabilities and integrating and testing them in operationally relevant environments (fast-time simulations, human-in-the-loop simulations, flight tests)
- Project consists of 6 technical sub-elements
  - **Roadmap**
  - **Integrated Test & Evaluation of key research areas**
  - **Separation Assurance & Collision Avoidance**
  - **Pilot-Aircraft Interface**
  - **Communications**
  - **Certification**

Where NASA will Focus



Roadmap for Civil UAS Access
- Support broader community in defining the success criteria for civil UAS in the NAS access

Separation Assurance and Conflict Avoidance
- Separation assurance in the NextGen environment
- Nominal and off-nominal sense and avoid

Communications
- Allocation of spectrum
- Robust data-link and satellite communications
- Secure data-link communications

UAS Pilot Aircraft Interface
- Pilot control interface
- Definitions of roles and responsibilities between pilots and controllers

Certification
- Airworthiness requirements, starting with systems and equipment
- Type design criteria

Integrated Test & Evaluation (IT&E)
- Simulations and flight tests *in a relevant environment*

Relevance of Project Focus Areas to Safety

- **Pilot Aircraft Interface**
  - This area was selected due to the number a UAS accidents attributed to poor pilot interface design with the intention of improving operational safety.

- **Separation Assurance**
  - All of the work in the separation assurance has a direct impact of the safety of the NAS.

- **Communications**
  - Work to secure the command and control link is driven by safety considerations.

- **Certification**
  - Certification is intended to develop the methodology by which designs are deemed safe for routine operation in the NAS.
  - Airworthiness requirements, starting with systems and equipment
  - Type design criteria

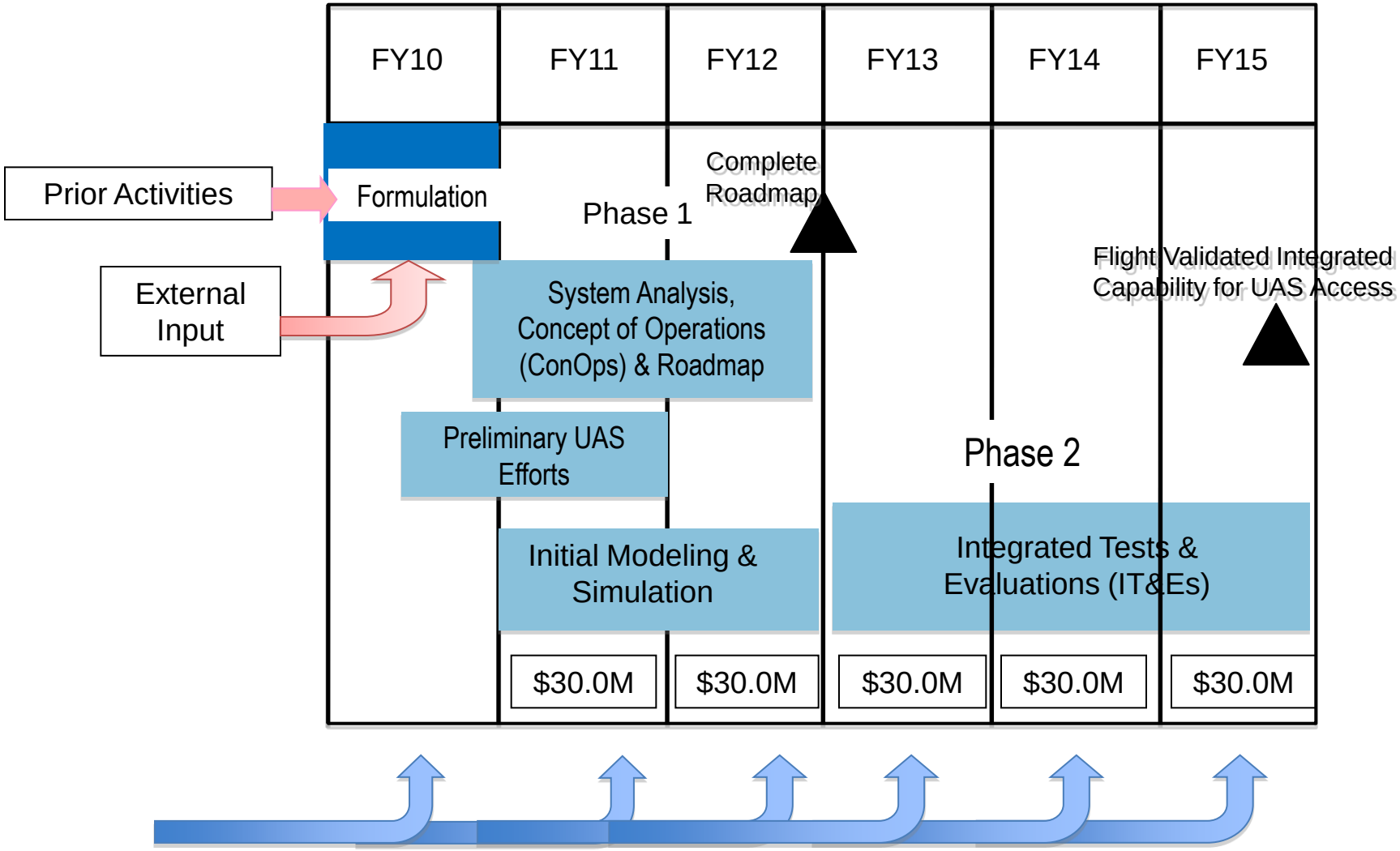
What We Are NOT Focusing On (In a Broad Sense)

- **NowGen Solutions**
  - Immediate Certificate of Authorization (COA) issues
  - Near-term technology development with limited long-term applicability
    - For example ground-based sense and avoid

- **Airframe Development**
  - Technology developments to improve a specific vehicle's performance.
  - Development of new vehicle capabilities (endurance, altitude, payload fraction, etc.).

- **Rule Making**
  - Data generated may support rule-making actions, but we will not work to develop any specific rule.

UAS Integration in the NAS Project Flow



Technical Input from Fundamental Programs, NASA Research Announcements (NRAs), Industry, Academia, Other Government Agencies

Phase 1 Roadmapping

- **Scope**
  - Support the national effort to develop a global civil UAS access plan
- **Objectives**
  - Leverage ExCom roadmapping efforts to develop the global civil UAS roadmap
  - Use the outputs to inform our Phase 2 IT&E test objectives
- **Approach**
  - Utilize a systems engineering process for developing a top-down plan
  - Leverage ARRA investments and FY10 In-Guide funding to complete the systems engineering product set
  - Early work in technology sub-elements will support roadmap detail development
- **Key Deliverables**
  - Version 1.0 of civil UAS Access Roadmap
- **Potential Partners**
  - UAS ExCom (DoD, DHS, FAA), JPDO, EUROCAE, RTCA, and other standards organizations

Partnership Relationships

UAS ExCom

- **This Committee is supported at very senior levels within the FAA, DoD, Department of Homeland Security (DHS), and NASA to address the immediate needs of public UAS access to the NAS. NASA has a role as both a provider of technology and a beneficiary of the outputs to enable science missions.**
  - Bi-weekly interactions are underway to understand issues and what each agency is currently doing to address each issue.

FAA

- **Direct interactions with relevant FAA organizations is necessary to ensure the Project understands their challenges. This will help validate the Project's course direction.**
  - Numerous meetings have occurred with the FAA UASPO, Air Traffic Organization, and Tech Center to ensure understanding and synergy.

JPDO

- **The JPDO is tasked with defining the Next Generation (NextGen) Air Transportation System. Since UAS must be incorporated into NextGen, this relationship is critical.**
  - Leverage already occurs with Aeronautics Research Mission Directorate primarily through the Airspace Systems Program. The Project has and will continue to meet routinely with JPDO to synch outputs with the national roadmap consistent with NextGen.

Industry Standards Organizations

- **The FAA relies on standards organizations to bring industry recommendations forward for consideration. Partnering with these organizations is essential to developing the data and technologies necessary for the FAA to approve civil UAS access.**
  - Ongoing participation in committees like RTCA Special Committees, ASTM, and the WRC

Partnership Interaction

PROJECT OUTCOMES

UAS ExCom
- NAS Access Roadmap (2011)
- COA W.G. deliverables (2011)

FAA R&D
- UAS 4DT NextGen Demos (2011)
- UAS Model Validation (2011-2015)

2011 | 2012 ★ | 2013 | 2014 | 2015 ★

NextGen ConOps; R&D Gap Assessment; Validated Technology Roadmap; Simulation Tools and Models

Real-time HITL sims to evaluate integrated technology applications; Fit test of integrated tech for proof of concept in relevant environment; inform regulator decisions for 2018-2010 IOC

2011 | 2012 ★ | 2013 | 2014 | 2015 ★

FAA UAS Program Office
- Command/Control Communication Link model development and validation (2013)
- Validated NAS-wide simulations of UAS traffic impact/compatibility (2014)
- Small UAS ARC (2011)

World Radio Conference
- Spectrum requirements (2012)
- RF Compatibility/sharing studies and analyses (2012)

Industry Standard Organizations
- Spectrum requirements (2012)
- RF Compatibility/sharing studies and analyses (2012)

JPDO
- UAS Integration in the NAS ConOps (2012)
- NextGen Roadmap including UAS (2012)

Project Milestones

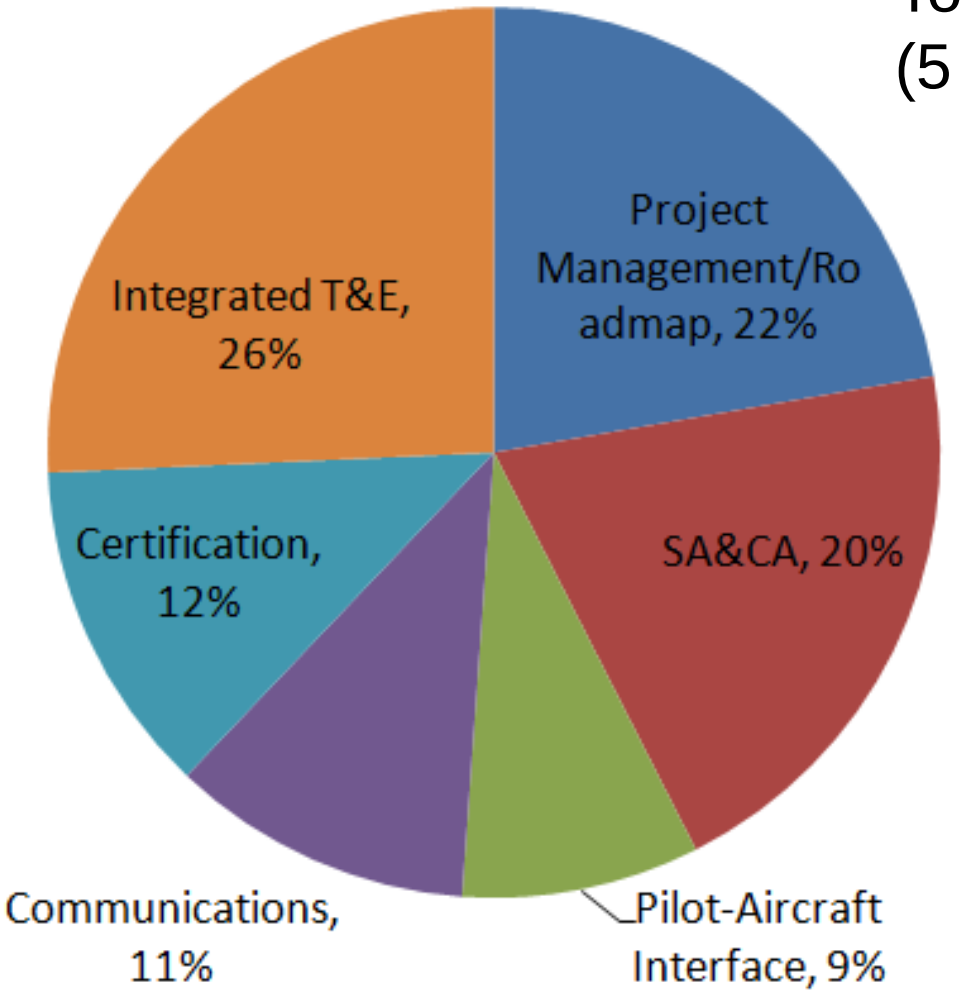
	FY 11	FY 12	FY 13	FY 14	FY 15
Road Map		Nat'l Roadmap Gap Analysis			
Separation Assurance & Collision Avoidance	UAS NAS Impact Study	Tactical SA Fast Time Sim Study	Tactical SA HITL	Off Nominal Ops HITL Tactical SA Flight Demo	Off Nominal Flight Demo CA Performance Requirements
Pilot Aircraft Interface	UAS in the NAS Human Factors Workshop Proceedings.	Draft of Guidelines for GCS compliance UAS in the NAS.		Final Guidelines for GCS compliance UAS in the NAS.	Integrated Flight Demonstration of NAS compliant GCS.
Communications	Provide data requirements and initial RF analysis for Working Party 5B frequency band studies CNPC threat and vulnerabilities analysis report	Provide RF analysis at World Radio Conference 2012 Candidate RF spectrum band simulations and in-situ measurements	CNPC Performance NAS-wide simulations	Prototype CNPC system performance Security mechanism performance simulations and in-situ measurements	CNPC impact on air traffic capacity NAS-wide simulations CNPC prototype compliance report
Certification	Gap analysis for hazard and risk-related data collection	Report on service-based approach to UAS classification and certification Comparative analysis of certification methodologies			Case study of candidate methodology for UAS airworthiness Reliability assessment for select UAS components, systems and subsys Report on UAS type design and best practices
Integrated Test & Evaluation	Fly Ikhana with ADS-B and FMS	Specific Objectives for Phase 2 integrated tests	HITL for SA, PAI and comm objectives Fly 2 UAS for SA and PAI objectives	Fly 3 UAS, 2 manned a/c for SA, PAI and comm objectives	Fly 3 UAS, 1 UAS Surrogate, 2 manned a/c for SA, PAI and comm objectives

Blue = Project Level Milestone

Budget Summary

Total Budget
(5 year run-out)

$150M

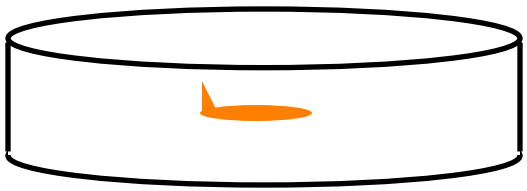


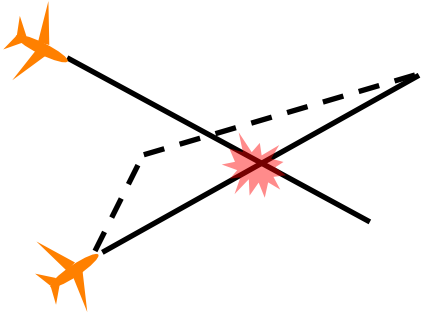
Acquisition Strategy

- Competitively awarded contracts will be used to engage the external community in collaborative development and field trials ensuring contributions from key technical expertise. Will use all available and necessary acquisition tools.
  - External procurements will be employed to a greater extent than current foundational research programs
- All four NASA Research Centers (Ames, Dryden, Glenn, and Langley) will participate with their unique competencies and facilities.
  - Approximately 45 FTE per year across all centers

Note: The acquisition strategy will be fully developed during the remaining formulation process and briefed to the Agency Associate Administrator for formal approval.

Separation Assurance and Collision Avoidance





Presented by: Todd Lauderdale

Meeting of Experts on NASA's Unmanned Aircraft System (UAS) Integration in the National Airspace Systems (NAS) Project

Aeronautics and Space Engineering Board
National Research Council
August 5, 2010

In Scope

- Real-time trajectory safety and contingency monitoring
- Mission planning for safety and to minimize impact
- Collision avoidance system requirements

Not in Scope

- “Sense and Avoid” sensors and algorithms will be developed by external partners

SA/CA Issues

Four areas of research:

- Tactical Separation Assurance Safety Systems
- Off-Nominal Procedures and Automation
- System Effects of UAS Inclusion
- Required Collision Avoidance System Performance

Tactical SA Safety Systems

- Air traffic controllers retain their responsibility for Separation Assurance
- Provide additional layer of safety and monitoring for UAS in Tactical Separation Assurance timeframe
- Real-time analysis of mission safety
- Leverage NASA NextGen technologies

Tactical SA Objective

- **Objective SACA-1**: Determine the level of safety provided by tactical separation assurance safety monitoring systems for UAS missions
  - *Rationale*: Continuous mission-risk monitoring can provide equivalent levels of safety for UAS operations possibly reducing the burden on other safety systems
  - *Approach*: Utilize and adapt algorithms and approaches developed for the NextGen Airspace Systems Program for UAS applications

Tactical SA Deliverables

FY	Deliverable	To	Used For
FY12	Safety data from fast-time simulation of UAS SA	FAA	Assess the viability and efficacy of Tactical SA safety systems
FY13	Algorithm effectiveness and controller/UAS operator acceptance from HITL study	FAA	Determine controller and operator acceptance of systems
FY14	Performance data of tactical separation assurance safety systems from flight test	FAA	Determine efficiency under uncertainty
FY15	Performance data of algorithm as part of integrated system from flight test	FAA	Determine integrated functionality under real conditions

Tactical SA Collaboration

- Partnerships: FAA - UAS models, controller expertise, scenario development
- Integrated Test and Evaluation:
  - Integrated Sim 1: Determine possible controller and UAS operator acceptance of UAS safety tools
  - Integrated Flight Test 2: Evaluate operation of safety tools with real latencies and trajectory uncertainties
  - Integrated Flight Test 3: Further evaluation of real world uncertainties and integration with off-nominal procedures

Off-Nominal Safety Assurance

- Defined by loss of communication and possibly other failures
- Since aircraft have no onboard pilot:
  - Aircraft may need to independently avoid other aircraft or regions of complex airspace
  - Also, may need to select overflight areas of low risk to ground infrastructure
- Provide automation alternative to some aspects of the flight authorization process

Off-Nominal SA Objective

- **Objective SACA-2**: Study off-nominal procedures and automation to assure safety of other aircraft and infrastructure in the event of a UAS off-nominal event such as loss of communication
  - *Rationale*: Off-nominal events are a barrier to UAS integration because there is no pilot for emergency decision making, so determining the appropriate procedures and automating those tasks will mitigate the risk of UAS operations
  - *Approach*: Leverage the contingency management experience of NASA and the off-nominal procedures work of external partners to provide tools for UAS safety in off-nominal conditions

Off-Nominal SA Deliverables

FY	Deliverable	To	Used For
FY12	Concept of operations for off-nominal procedures defined	Internal	Determine accepted risk mitigation procedures for automation
FY13	Performance of off-nominal procedures in fast-time simulations	FAA	Assess automation for off-nominal risk mitigation
FY14	Data supporting controller and operator acceptability of from HITL assessment	FAA	Determine acceptability of off-nominal procedures for UAS operators and controllers
FY15	Off-nominal automation performance in integrated environment from flight test	FAA	Study integrated system performance of off-nominal SA under real flight conditions

Off-Nominal SA Collaboration

- Partnerships: DoD - off-nominal processes and procedures; FAA - flight authorization process
- ARRA: Contingency management ConOps
- Integrated Test and Evaluation:
  - Integrated Flight Test 3: Evaluate performance and acceptability of off-nominal procedures and automation with real latency and uncertainty

System Effects of UAS

- Often have different performance characteristics than manned aircraft
- Often fly different routes than manned aircraft
- Systems studies will provide:
  - Mission safety assessments and risk mitigation tools
  - Impacts of UAS operations on other NAS stakeholders

System Effects Objective

- **Objective SACA-3**: Study the effects of inclusion of specific UAS and missions in the NAS to determine the probable impact of the UAS mission on safety and other NAS stakeholders
  - *Rationale*: The current risks and difficulties associated with mixed UAS operations can be studied to determine their impact and develop tools and procedures to mitigate this impact
  - *Approach*: Use NASA airspace modeling resources to evaluate UAS impact and to identify risk reduction strategies for specific UAS missions

System Effects Deliverables

FY	Deliverable	To	Used For
FY11	Data quantifying impact of UAS and missions on current NAS	FAA	Assess the impact unique aspects of UAS and missions on NAS safety and efficiency to help determine required technologies
FY13	Data from analysis of safety and risk for specific UAS	FAA	Help determine the safety risks in terms of aircraft and infrastructure of a UAS mission
FY15	Mission planning tool to minimize UAS risk and enable contingency management	FAA, UAS operators	Allows for UAS mission planning to minimize NAS impact while maintaining mission goals

System Effects Collaboration

- Partnerships: FAA - Collaboration and sharing of fast-time modeling results and scenario development
- Scenario and model sharing with Communications simulation effort

Collision Avoidance Requirements

- Focus on system performance requirements instead of component design
- Generate data to determine the required performance of a CA system
- Different requirements may be necessary for different UAS classes and missions

CA Objective

- **Objective SACA-4**: Provide data supporting possible requirements for the performance of collision avoidance systems for specific UAS and situations
  - *Rationale*: There are many collision avoidance algorithms and sensors under development, but no functional requirements to verify system performance
  - *Approach*: Generate data on collision avoidance performance requirements using simulation expertise

CA Deliverables

FY	Deliverable	To	Used For
FY12	Survey of current systems CA systems and requirements used	Internal	Inform future research into CA requirements of current system performance
FY12	Assessment of previous CA requirement specification methodologies	Internal	Inform methodologies for determining required performance
FY14	Data from simulations to determine CA performance requirements	FAA	Large scale assessment of different UAS collision risks and performance characteristics
FY15	Candidate CA system requirements from compiled safety data from simulations	FAA	Provide a design standard for CA system performance

CA Collaboration

- Partnerships: FAA - Collaborate on desired data for analyses and requirement generation; DoD - Input on sense and avoid systems and performance
- ARRA: Survey of “Sense and Avoid” capabilities

Facilities

- Air Traffic Control Lab – Ames
- Air Traffic Operations Lab - Langley
- Airspace Operations Lab - Ames
- IDEAS Lab – Langley
- Small UAS aircraft and operations labs – Ames, Langley, Dryden
- Manned surrogate UAS – Langley
- Ikhana MQ-9 - Dryden

Pilot Aircraft Interface Objectives/ Rationale

Presented by: Mr. Jay Shively
Pilot Aircraft Interface Technical Area Lead

Meeting of Experts on NASA's Unmanned Aircraft System (UAS) Integration in the National Airspace Systems (NAS) Project

Aeronautics and Space Engineering Board
National Research Council
August 5, 2010

Pilot Aircraft Interface Issues

- UAS Pilot/Operator
  - **Loss of senses**
    - Audition
    - Vestibular Cues
    - Olfactory
    - Monocular vision & reduced FOV (e.g., 30 degrees)
- Long duration missions
- Crew handovers
- No standard requirements/training
    - USAF - rated pilots
    - Army - specially trained soldiers
    - Raven operators - one week of training

Pilot Aircraft Interface Issues

- Ground Stations
  - **Lack of standardization**
  - **Lack of application of 70+ years manned cockpit experience**
  - **Huge disparity in level of automation & proposed use of NAS**
    - Raven, Predator, Shadow, Global Hawk
  - **Rush to service**
    - Advanced Concepts Technology Demonstrations
    - Engineering displays became operational
      - **Improved GCS efforts are underway**
  - **Proprietary**
  - **Generally not built with eye toward NAS**
  - **UAS specific issues**
    - Delays
    - Loss of link
    - Contingency operations
    - Link strength/Type
    - Data-link Frequency Use
    - Vehicle Speed/maneuverability (pilots and ATC)
    - Shifting human-automation functional allocation (particularly for SA/CA & landings)

Scope

In scope:

- NASA will address those issues related to UAS integration into the NAS – based on information requirements analysis
- Develop guidelines for a UAS/GCS to operate in the NAS/ Demonstrate proof of concept
- Generic PAI issues (e.g., operator FOV) when needed to effectively test UAS-NAS integration

Out of scope:

- Determination of pilot v. non-pilot qualifications for UAS operation

Scope

Primary*

Support

Class of UAS User Interaction	Airspace Req'd	Cap/ Req
Small (Raven) R/C, Portable	G (2k), TFR	Ground based ?
Mid-Size (Shadow) Semi-Auto, Mobile	E (10k)	Sense & Avoid, Traffic
Large (Predator) Manual, Fixed	A (18-45k)	Sense & Avoid, Traffic
Large (Global Hawk) Auto, Fixed	A, E (18-60k)	Sense & Avoid, Traffic

*** Employed by DHS, USAF, Army**

Pilot Aircraft Interface Definitions

- PAI – Pilot Aircraft Interface (includes visual, auditory, tactile displays and controls)
- GCS – Ground Control Station
- SA – Situation Awareness = sum of informational elements aggregated in context sensitive nodes weighted by importance
- Workload – Effort expended to perform the required task (NASA-TLX, Secondary tasks)
- UAS Pilot/operator – “Controller” of UAS
- Full Mission Simulation – High fidelity, integrated with ATC sim, SA/CA

PAI Objectives

- **Objective: Database and proof of concept for guidelines for GCS compliance**
  - *Rationale*:
    - Provide research test-bed to develop guidelines
    - Modify GCS for NAS Compliance to provide proof of concept
  - *Approach*:
    - Assess current state of GCS technology
    - Information Requirements Definition
    - SME Workshop
    - Modify an Existing GCS for NAS Compliance
    - Define exemplar UAS (choose system to develop prototype)
    - Define Candidate Displays & Controls
    - Evaluate/ refine in Simulations
    - Demonstrate in flight
  - *Deliverables:*
    - Information Requirements Report
    - Workshop Proceedings
    - Technical Reports/ papers on Simulations & Flight Demo
    - Database for guidelines

Database and proof of concept for guidelines for GCS compliance

FY	Deliverable	To	Used For
	Phase I		
11	Proceedings of UAS In the NAS HF Workshop	DoD, tech elements, Industry	Req'ts & Sim
11	Info Requirements	DoD, Industry	Guidelines and sims
	Phase II		
12	Candidate PAI Suite	DoD, Industry	PAI refinement
14	Full Mission Simulation	DoD, Industry	+ Guidelines
15	Integrated Flight Demo	DoD, Industry	Proof of concept

PAI Objectives

- **Objective: Develop Human Factors Guidelines for GCS Operation in the NAS**
  - *Rationale*:
    - Provide guidelines for GCS integration into the NAS
    - Encourage standardization of primary flight displays (especially with respect to operation in the NAS)
    - Publish in conjunction with standards organization
  - *Approach*:
    - Define Scope/Issues
    - Identify on-going efforts (military, foreign)
    - Identify appropriate standards organization
    - Develop guidelines for exemplar UAS
    - Develop guidelines for remaining classes of UAS
  - *Deliverables:*
    - Technical Reports
    - Guidelines

Develop Human Factors Standards/Guidelines for GCS Operation in the NAS

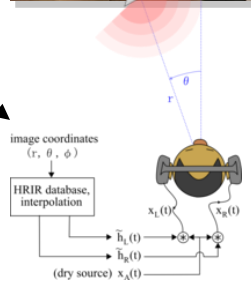
FY	Deliverable	To	Used For
	Phase I		
12	Guidelines for 1st Category of UAS	Std. Org, DoD, Industry	Compliance and basis for additional classes
	Phase II		
13	Draft Guidelines for 2nd/3rd Category of UAS	Std. Org, DoD, Industry	Comment/Review
14	Final Document	Std. Org, DoD, Industry	Guidelines for Compliance

Notional Vision

4D Separation Tools

Tactile Displays

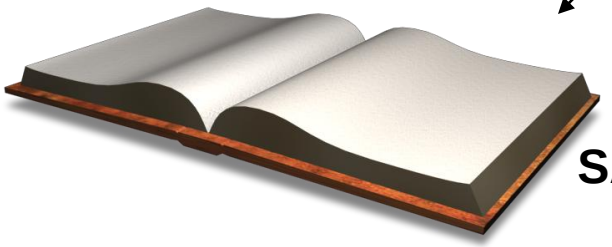
Spatial Audio Warning



Traffic on Tactical Sit. Display (TSD)

Integrated Into caution, warning, advisory

Supervisory Control/ Level Of Automation



Guidelines

SAE, RTCA

U.S. AIR FORCE

UAS Industry

U.S.ARMY

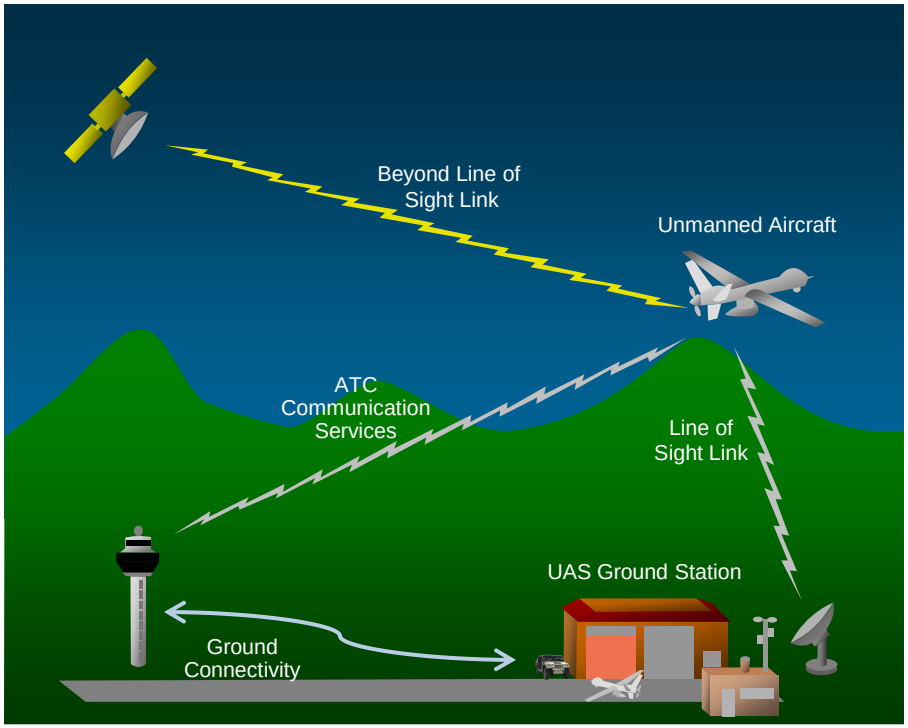
Initial Partnering Effort: Workshop

- Objectives:
  1. **Hold workshop to identify critical Human Factors issues related to operation of UAS in the NAS from the perspective of researcher, stakeholders (e.g. DHS, DoD), and users (i.e. UAS operators/pilots) [Day 1&2].**
  2. **Review and receive feedback on current PAI plan to ensure key areas are being addressed [Day 2].**
- Attendees
  - **UAS Human Factors Researchers:**
    - AFRL, Navy, BYU, MIT, ASU, Texas A&M, U of Illinois, OSU
  - **Representatives from Stakeholders from:**
    - Air Force, Army, Navy, FAA, and DHS
  - **UAS Operators/Pilots**
- Deliverable
  - **Workshop Proceedings: documenting the efforts undertaken for this program and other efforts in the area of UAS human factors. Can serve as input to a larger Roadmap for UAS integration into the NAS**

Facilities

- Multi-UAV Simulation (MUSIM) – Ames
- Air Traffic Control Lab – Ames
- Universal Ground Control Station – Dryden
- Flight Deck Display Research Lab – Ames
- Air Traffic Operations Lab - Langley
- Operational AIRSTAR GCS – Langley
- IDEAS Lab – Langley
- Small UAS aircraft and operations labs – Ames, Langley, Dryden
- Manned surrogate UAS – Langley
- Ikhana MQ-9 - Dryden

Communication



Presented by: Jim Griner
Communications Technical Lead

Meeting of Experts on NASA's Unmanned Aircraft System (UAS) Integration in the National Airspace Systems (NAS) Project

Aeronautics and Space Engineering Board
National Research Council
August 5, 2010

Communication Issues

- UAS are currently managed through exceptions and are operating using DoD frequencies for line-of-sight (LOS) and satellite-based communications links, low-power LOS links in amateur bands, or unlicensed Instrument/Scientific/Medical (ISM) frequencies. None of these frequency bands are designated for Safety and Regularity of Flight.
- No radio-frequency (RF) spectrum has been allocated by the International Telecommunications Union (ITU) specifically for UAS command and control links, for either LOS or Beyond LOS (BLOS) communication.

Reliable command and control communications systems are essential for UAS operations in the NAS.

What We Heard They Wanted

RTCA SC-203, FAA Tech Center, FAA Flight Standards

- Would like NASA's assistance on spectrum studies for WRC-12.
- No work has been performed on communication security in SC-203 for the past two years, due to a lack of SMEs consistently working in this area.
- Requirements values being developed are only "seed values." They need NASA's SMEs for validating/updating these requirements based on modeling and simulation results as well as requirements validation via prototype candidate technologies.
- Requirements development has mainly focused on communication latency. They need NASA SMEs for requirements development in the areas of continuity, availability, and integrity.
- Architectures including ground based connections between UAS pilots and FAA/ATC have not been fully vetted as viable for UAS communication. This architecture may be necessary to meet current communication latency requirements. Need NASA SMEs for analysis and vetting of this architecture for compatibility with UAS and NextGen.

Prior/Ongoing Work

- NASA's communication work for the UAS Command and Control area will build upon work currently being conducted under NASA Recovery Act funds
  - Communication portions of UAS NextGen ConOps, State-of-the-Art assessment, and Gap Analysis
  - Preliminary simulations for UAS CNPC link scalability assessment
  - Surrogate UAS aircraft upgrades
- This work will also leverage FY10 in-guide funding for communication link model development

Communication Scope

- Command and Non-Payload Communication (CNPC) Spectrum for both LOS and BLOS connectivity
- CNPC Datalink
- CNPC Security
- CNPC Scalability & ATC Communication Compatibility

Not in Scope

- Changes to existing and planned FAA Communication/Navigation/Surveillance systems
- Onboard Communications & DataBus Technologies

Partnerships

- Government Agencies

  FAA: Sim & Modeling, Security

  DoD: Requirements, Standards, Performance Based Comm

  DHS: Requirements, Standards

- Standards/Regulatory Bodies

  ITU-R: Requirements, RF Compatibility/Sharing Analysis

  RTCA SC-203: Requirements, Security, Sim & Modeling, Validation Data

  ASTM F38: Requirements for Small UAS Class

RF Spectrum Objective

- **Objective 1**: Obtain appropriate frequency spectrum allocations in both the US and international frequency regulations to enable the safe and efficient operation of UAS in the NAS.
  - *Rationale*: Currently there are no RF spectrum allocations in either national or international frequency regulations designated for use by UAS in civilian airspace for safety-of-flight command and non-payload communication
  - *Approach*: Participate and contribute to the work of ITU-R Working Party 5B (the international group responsible for obtaining UAS spectrum at the next World Radio Conference in Jan/Feb 2012) by conducting compatibility/sharing analyses and providing needed data. This work will be conducted in partnership with other US government agencies (e.g. FAA, DoD, DHS) and commercial entities (e.g. UAV manufacturers) within national and international spectrum/regulatory bodies.

RF Spectrum Deliverable

- **Objective 1**:

FY	Deliverable	To	Used For
12	Compatibility/sharing studies and analyses, communication data requirements, and regulatory text	ITU Working Party 5B	Provides supporting data to obtain spectrum allocation for UAS Command and Control Communication

Datalink Objective

- **Objective 2**: Develop and validate candidate UAS CNPC system/subsystem prototype that comply with UAS international/national frequency regulations, ICAO SARPs (Standards and Recommended Practices), and FAA/RTCA MOPS/MASPS (Minimum Operational Performance Standards/Minimum Aviation System Performance Standards) for UAS
  - *Rationale*: UAS CNPC terrestrial and satellite systems must be designed and developed that are RF compatible with other existing or planned radio services and systems operating in the candidate spectrum bands and also meet the performance and safety requirements specified in aviation standards currently being developed for UAS in ICAO and FAA/RTCA (i.e. SARPs,MOPS,MASPs,etc).
  - *Approach*: Participate and contribute to regulatory/standards organizations developing frequency, safety, and performance requirements for UAS CNPC. Design prototype CNPC systems/subsystems that are compliant with these requirements through necessary technical analyses, simulations, and test measurements. Develop and test one or more prototype CNPC systems to assess performance and validate proposed system requirements. Validate performance during integrated testing with Pilot Aircraft Interface and SA/CA.

Datalink Deliverables

- **Objective 2**:

FY	Deliverable	To	Used For
12	Report on RF channel simulations and in-situ measurements	Applicable Standards/ Regulatory Bodies (ITU, ICAO, NTIA, RTCA, JAUS, ASTM, etc.)	Provides technical analysis to justify and obtain permanent spectrum allocation for UAS Command and Control Communication, and validation of proposed UAS communication standards
13	Prototype CNPC system design and lab validation documentation	“	“
14	Report on prototype performance validation in a relevant environment	“	“
15	Prototype performance validation in a mixed traffic environment report	“	“

Security Objective

- **Objective 3**: Perform analysis and propose CNPC security recommendations for public/civil UAS operations
  - *Rationale:* Most current aviation safety voice and datalinks do not include security measures, and there has been increasing threats and vulnerabilities to both RF and network subsystems due to the ease of access to equipment and networks by the general public.
  - *Approach:* Participate and contribute to regulatory/standards organizations developing safety, security, and performance requirements for UAS CNPC. Perform analysis, testing, and mitigation against security risks to the confidentiality, availability, and integrity of the integrated ATC and CNPC communications systems. Propose requirements and develop architectures/standards to support these requirements. Perform integrated testing to validate performance in a relevant environment.

Security Deliverables

- **Objective 3**:

FY	Deliverable	To	Used For
11	Threat and vulnerability assessment report on RF and network systems expected to be employed in the CNPC operations	FAA	Provides supporting data for decision on UAS communication system risk acceptance vs risk mitigation
12	Risk mitigation strategy report identifying options for securely deploying a CNPC system	FAA & Standards Bodies	“
13	Prototype communications system security architecture design and laboratory validation documentation for CNPC	Applicable Standards Bodies (ITU, ICAO, RTCA, JAUS, etc)	Developing security portion of UAS communication system architecture/standards for an International environment
14	Report on prototype security architecture performance validation in a relevant environment	“	“

System Scalability Objective

- **Objective 4**: Perform analysis to support recommendations for integration of CNPC and ATC communications to ensure safe and efficient operation of UAS in the NAS
  - *Rationale*: Current aeronautical datalinks are separate networks providing relatively low-bandwidth with a modest number of concurrent subscribers in any given area. The introduction of UAS in the NAS has the potential to drastically increase the aeronautical traffic densities, thus dramatically increasing the data requirement for the available links.
  - *Approach*: Develop CNPC system link models for all UAS classes to predict performance during all phases of flight. Perform NAS-wide simulations of mixed traffic to determine CNPC and ATC communication system performance impact on air traffic delays and system capacity. Validate performance during integrated simulations and flight testing with Pilot Aircraft Interface and SA/CA.

System Scalability Deliverables

- **Objective 4**:

FY	Deliverable	To	Used For
12	Models for UAS CNPC systems	FAA	Updating models to include UAS communication system for capacity and forecast tools, used for airspace system planning and deployment
13	Report on NAS wide communication system performance utilizing candidate communication technologies	Applicable Standards/ Regulatory Bodies (ICAO, RTCA, JAUS, ASTM, etc.)	Choosing UAS communication system architecture based on scalability of communication system and its impact on manned aircraft
15	Report on communication system performance impact on air traffic delays and system capacity.	FAA	Updating models to include UAS communication system for capacity and forecast tools, used for airspace system planning and deployment

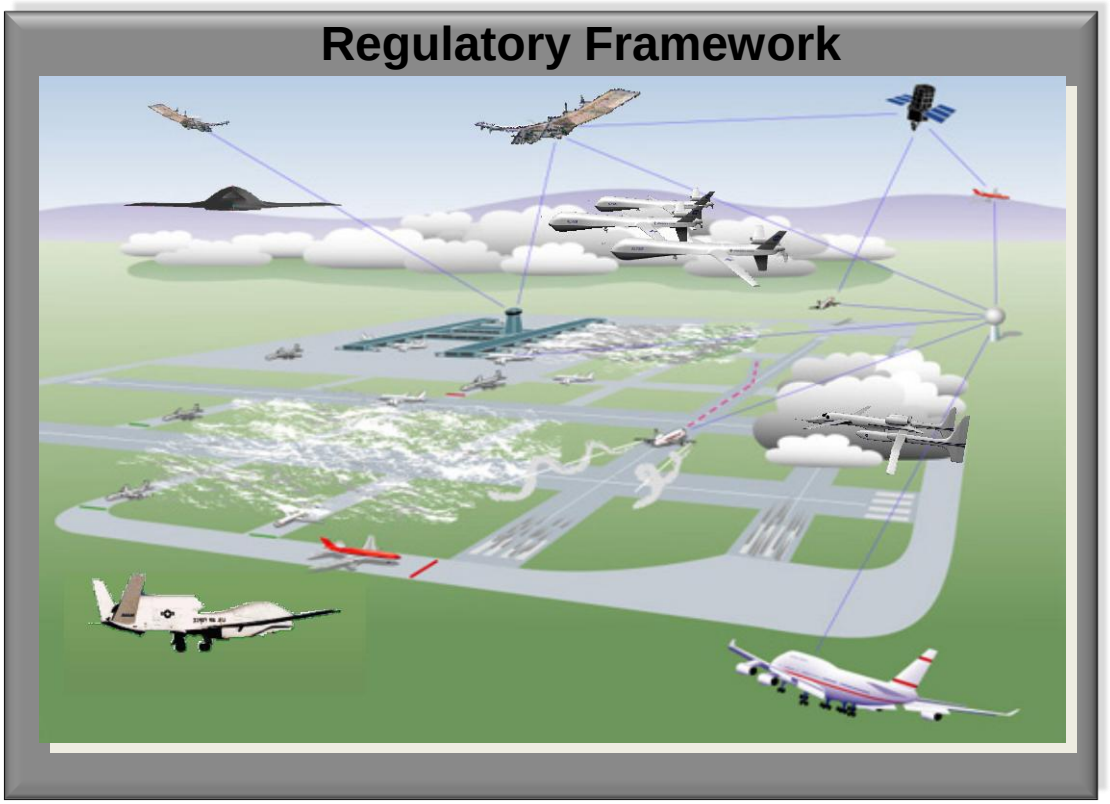
Integrated Tests & Evaluation

- **Integrated Sim 1 (Year3)**
  - Simulated CNPC comm and security protocols in conjunction with tactical SA algorithms to evaluate interaction between CNPC datalink and SA algorithms.
- **Integrated Flight Test 3 (Year 4)**
  - One of the manned aircraft will employ the CNPC datalink and security systems, for evaluation of PAI GCS and SA/CA algorithms.
- **Integrated Flight Test 4 (Year 5)**
  - Flight evaluation of an integrated PAI/NAS compliant GCS equipped with candidate CNPC datalink to assess communication latencies, RF compatibility in a relevant environment, and Separation Assurance performance

Facilities

- Wireless Communication Lab - Glenn
- Aircraft Communication Simulation Lab - Glenn
- T-34C Surrogate UAS - Glenn
- S-3B Aircraft - Glenn

Certification



Presented by: Kelly Hayhurst
Langley Research Center

Meeting of Experts on NASA's Unmanned Aircraft System (UAS) Integration in the National Airspace Systems (NAS) Project

Aeronautics and Space Engineering Board
National Research Council
August 5, 2010

Where Certification Fits

- **Routine access to the NAS for UAS hinges on establishing that UAS can *operate safely* in the NAS**
  - Technologies that enable safe operation
    - Separation assurance
    - Communication
    - Command and Flight Control
    - Human Factors/Pilot Aircraft Interfaces
  - A regulatory framework that defines safe operation
    - acceptable means of compliance to the Federal Aviation Regulations (FARs) through standards and other guidance

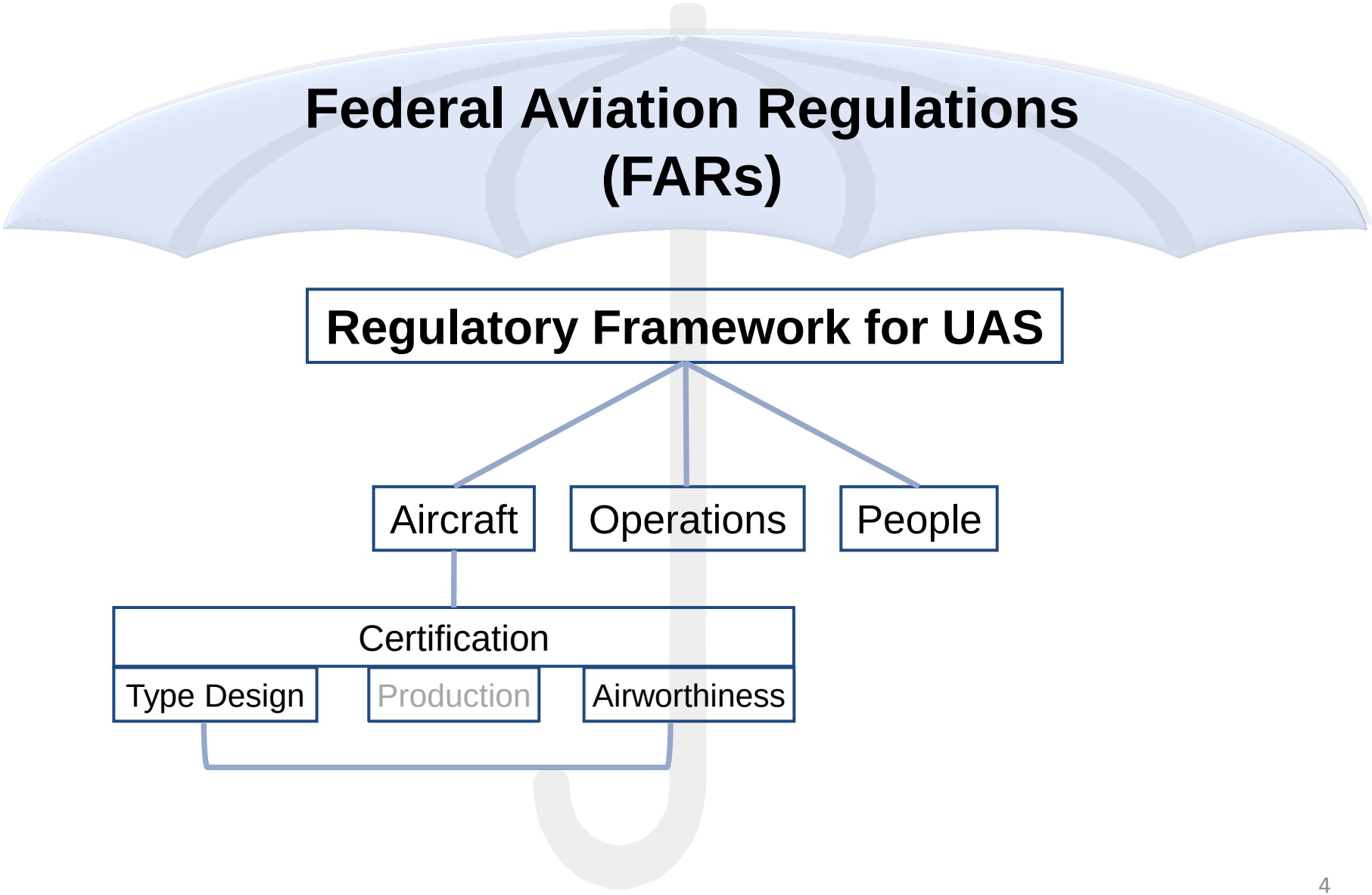
Context

"UAS operation in civil airspace means flight over populated areas must not raise concerns based on overall levels of airworthiness; *therefore*,

UAS standards cannot vary widely from those for manned aircraft without raising public and regulatory concern."

– from FY2009–2034 Unmanned Systems Integrated Roadmap

Scope


Federal Aviation Regulations (FARs)
Regulatory Framework for UAS
Aircraft
Operations
People
Certification
Type Design
Production
Airworthiness

Certification & Airworthiness

Certification includes regulations, standards and other guidance necessary to provide assurance of the intrinsic safety and airworthiness of an aircraft

- **conforms to its type design and is in a condition for safe flight**

Key concepts :

- **assuring that systems and equipment perform their *intended functions* under any foreseeable operating condition**
- **assuring that *unintended functions* are improbable**

- from FAR 23 & 25.1309

Certification Issues

- **Working with existing regulations for a relatively few aircraft types and operations, when there are many diverse UAS types and operations**
- **Working without the benefit of relevant data to support risk assessment and regulation development**
  - incident and accident data
  - reliability data
- **Knowing that the pilot in command may not always be capable of discontinuing flight when un-airworthy mechanical, electrical, or structural conditions occur**
- **Increased reliance on automation (especially software) for safety**

Airworthiness Requirements

Allowable Probabilities of failure & Design assurance levels

Classification of Failure Conditions	No Safety Effect	Minor	Major	Hazardous	Catastrophic
Part 23 Class I	No Requirement	$<10^{-3}$ Level D	$<10^{-4}$ Level C	$<10^{-5}$ Level C	$<10^{-6}$ Level C
Part 23 Class II	No Requirement	$<10^{-3}$ Level D	$<10^{-5}$ Level C	$<10^{-6}$ Level C	$<10^{-7}$ Level C
Part 23 Class III	No Requirement	$<10^{-3}$ Level D	$<10^{-5}$ Level C	$<10^{-7}$ Level C	$<10^{-8}$ Level B
Part 23 Class IV Commuter	No Requirement	$<10^{-3}$ Level D	$<10^{-5}$ Level C	$<10^{-7}$ Level B	$<10^{-9}$ Level A
Part 25 Transport	No Requirement	$<10^{-5}$ Level D	$<10^{-5}$ Level C	$<10^{-7}$ Level B	$<10^{-9}$ Level A

- **These requirements drive the design of systems and equipment**

What would be acceptable for UAS?

Complying with 1309 requirements

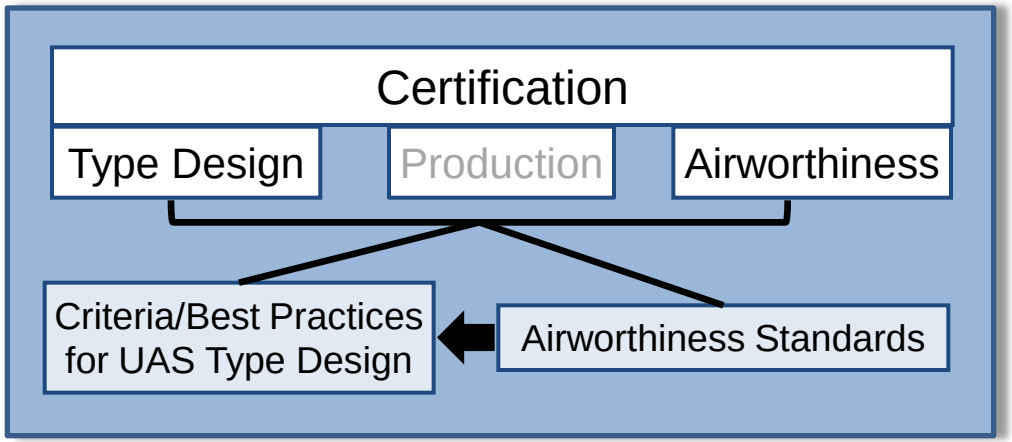
Classification of Failure Conditions	No Safety Effect	Minor	Major	Hazardous	Catastrophic
UAS Class I?	*No Requirement*	?	?	?	?
UAS Class II?	*No Requirement*	?	?	?	?
UAS Class III?	*No Requirement*	?	?	?	?
…	*No Requirement*	?	?	?	?

A general classification scheme that enables determination of appropriate values is still a challenge!

Classification/Airworthiness Conundrum

- **What parameters are needed for UAS classification that facilitate definition of 1309-type requirements?**
- **Can we take a service-based approach?**
  - **using RTCA/DO-264 for a specific UAS service**
    - for example, fire monitoring, communication tower

Type Design



Type Design consists of the drawings and specifications necessary to define aircraft configuration and design features needed to comply with airworthiness standards

- **What is needed to facilitate UAS designs that can comply with airworthiness standards?**
  - **lessons learned from incident and accident data**
    - **from use in military context and use under COAs**
  - **reliability data for system components unique to UAS**
  - **assessment of UAS-specific hazards and risks**

→ **Best practices for UAS design for airworthiness**

Certification Objective 1

- **Objective 1: Provide regulators with a methodology for development of airworthiness requirements for certification of UAS**
  - *Rationale*: a comprehensive methodology does not currently exist to support development of regulation for certification of UAS. Regulation is essential to enable routine access to the NAS.
  - *Approach*:
    1) assess existing approaches and classification schemes for deriving acceptable means of compliance to airworthiness requirements
    2) investigate a service-based approach to classification of UAS
    3) conduct comparative analysis of different methodologies
    4) work with FAA to determine best approach and conduct case study
    5) participate in regulatory/standards organizations developing safety and performance requirements for UAS

Certification Objective 1

– *Deliverables:*

FY	Deliverable	To	Used For
11	Initial assessment of approaches to airworthiness requirements	FAA	Decision aid for formulation of UAS airworthiness standards
12	Report on service-based approach to UAS classification	FAA	Decision aid for formulation of UAS airworthiness standards
12	Comparative analysis of certification methodologies for UAS	FAA	Decision aid for formulation of UAS airworthiness standards
14	Case study of certification methodology	FAA	Decision aid for formulation of UAS airworthiness standards
15	Final report on UAS certification methodology	FAA	Decision aid for formulation of UAS airworthiness standards

Certification Objective 2

- **Objective 2: Provide regulators and industry with hazard and risk-related data to support criteria for UAS type design**
  - *Rationale:* There is presently little UAS specific data (incident, accident, and reliability), especially in a civil context, to support risk assessment and development of standards and regulation.
  - *Approach:* Identify gaps in existing data, provide measured data as needed, and formulate recommendations by:
    1) evaluating UAS incident/accident data collection efforts and determining additional support necessary for regulation
    2) assessing UAS-specific hazards and risks
    3) evaluating need for reliability data for UAS-unique systems, components and subsystem, and determining additional measurement requirements
    4) developing guidance and best practices for UAS type design

Certification Objective 2

– *Deliverables:*

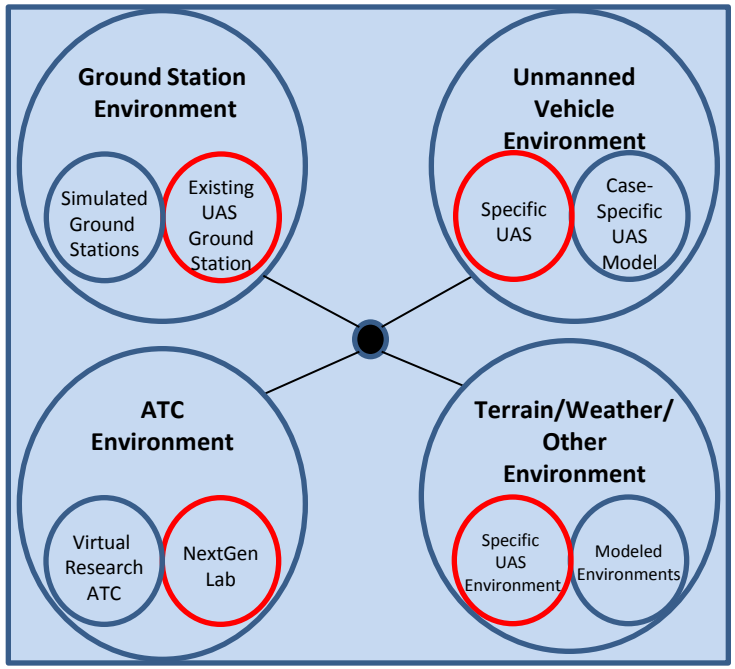
FY	Deliverable	To	Used For
11	Report on gap analysis for UAS incident and accident data	FAA	Determining needs for accident & incident reporting to support UAS regulation
11	Report on gap analysis for UAS component reliability	FAA, Industry	Development of risk assessments and potential regulatory requirements
12	Report on UAS hazards and risk assessment	FAA, Industry	Use in development of UAS regulation
12	Report on implications of hazard/risk to regulation	FAA, Industry	Development of risk assessments and potential regulatory requirements
15	UAS Type Design recommendations	FAA, Industry	Best practices for UAS developers & users

Partnerships, Links, and Integrated Test and Evaluation

- **Partnership with the FAA Tech Center and UAS Program Office, US Air Force, and US Army**
  - other informal coordination with RTCA SC-203, NATO STANAG 4671 Custodial Support Team, and ASTM
- **Links to FY10 In-Guide Funding**
  - linked with certification-related aspects of the roadmap and CONOPS
- **Links to Integrated Test and Evaluation**
  - there are preliminary expectations for the case study to leverage IT&E simulation and flight tests
    - difficult to clarify specific needs until the comparative analysis of approaches is complete

Facilities

- **That could support a certification case study**
  - Simulation Development & Analysis Branch Simulators – Langley
    - Test & Evaluation Simulator (TES)
    - Differential Maneuvering Simulator (DMS)
  - Air Traffic Operations Lab (ATOL) – Langley
  - AirSTAR Ground Control Station/Mobile Operation Station (MOS)/Generic Transport Model (GTM) Simulator – Langley
  - Manned surrogate UAS – Langley
  - FAA Tech Center UAS and NextGen lab facilities – FAA Tech Center
  - Ikhana – Dryden
- **Supporting small UAS type design studies**
  - SUAVELab – Langley
  - Electrochemistry Branch Testing Lab – Glenn



Notional Validation Architecture
supporting the case study

Integrated Tests and Evaluations

Presented by: CJ Bixby
Project Systems Engineering Lead

Compiled by: Jim Murphy and Sam Kim
Integrated Tests and Evaluations Co-Leads

Meeting of Experts on NASA's Unmanned Aircraft System (UAS) Integration in the National Airspace Systems (NAS) Project

Aeronautics and Space Engineering Board
National Research Council
August 5, 2010

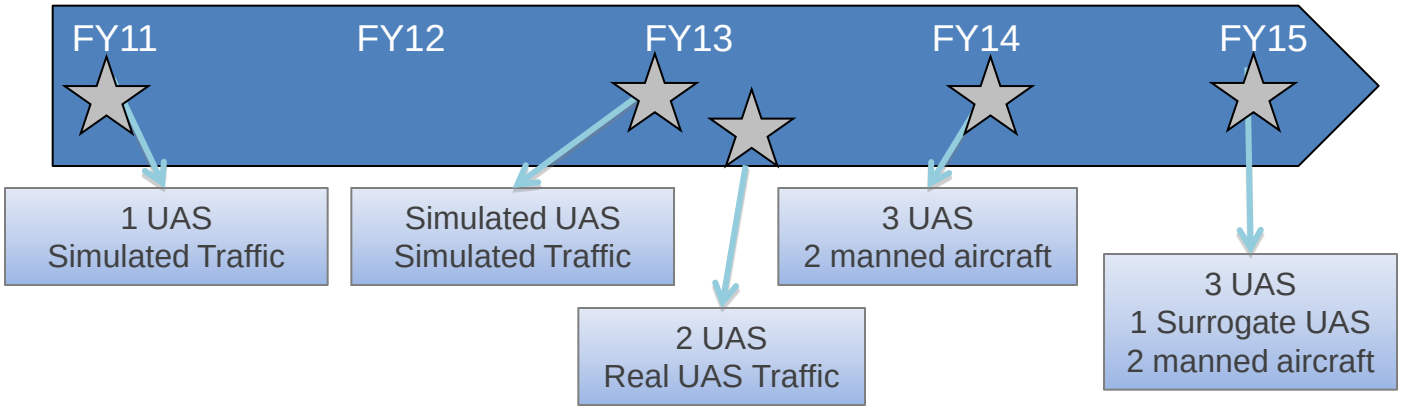
Integrated Tests and Evaluations

- Simulations and flight demonstrations cut across technical areas
- Represent the culmination of many focused tests conducted by each subelement.
- Provide complex and relevant environments in which to evaluate and validate the work of the subelements

Provide systems-level, integrated concepts that address barriers to routine access to the NAS. Through simulation and flight testing, address issues including separation assurance, communications requirements, and human factors issues in operationally relevant environments.

Integrated Tests and Evaluations Approach

- Use phase I to do detailed test planning for phase II
- Assist subelements with test planning
  - Assist with documenting test objectives, data and facilities/infrastructure requirements, and detailed test planning
  - Provide facilities/infrastructure to meet test requirements
  - Provide interfaces between tools
  - Develop, document, and execute data handling and dissemination plans
  - Provide a test engineer to facilitate scheduling of facilities, support specific equipment and software needs, track schedule progress, and monitor changes to schedule
  - Provide guidance for alternative facilities or equipment to mitigate risk associated with loss of availability
- Provide opportunities for subelements to gather data in relevant and increasingly complex environments



UAS Integration in the NAS IT&E Milestones

	End of Year 1	End of Year 2	End of Year 3	End of Year 4	End of Year 5
Roadmap	• Draft Roadmap for Federal Public Access	• Gap Analysis and State of the Art Assessment			
SA CA	• Fast time Sim • NowGen NAS • Nominal UAS Ops • Baseline	• Fast time Sim • NextGen NAS • Tactical SA • Nominal UAS Ops	• HiTL Sim • NextGen NAS • Tactical SA • Nominal UAS Ops	• HiTL Sim • NextGen NAS • Tactical SA • Off-nominal UAS Ops • Flight Demo • NextGen NAS • Tactical SA • Nominal UAS Ops	• Flight Demo • NextGen NAS • Tactical SA • Nominal and Off-nominal UAS Ops
PAI			• Develop prototype NAS compliant GCS • Conduct SIMs	• Final GCS Guidelines	• Flight Demo • Prototype GCS/display suite
Comm			• Develop candidate CNPC protocol and security implementation • Conduct Sims	• Fly CNPC suite on T-34C	• Fly CNPC suite in mixed traffic
IT&E	• Ikhana Flight • ADS-B + FMS • Support FAA demo • Integrate GCS + Sims • Prep for future demos	• Specific objectives for Phase II tests	• HiTL Sim • NextGen NAS • Tactical SA • Nominal UAS Ops • NAS compliant GCS • CNPC protocol and security implementation • Flight Demo • NextGen NAS • Tactical SA • NAS compliant GCS	• Flight Demo • NextGen NAS • Tactical SA • Nominal UAS Ops • NAS compliant GCS • CNPC protocol and security implementation • Cert case study data • 2 UAS / multiple manned A/C	• Flight Demo • NextGen NAS • Tactical SA • Nominal and Off-nominal UAS Ops • NAS compliant GCS • CNPC protocol and security implementation • Cert case study data • 3+ UAS / multiple manned A/C

Integrated Tests and Evaluations

- Partnerships and Leveraging Other Work
  - IT&E inherits partnerships from the subelements.
  - Partnership with FAA provides FAA with build up for their demo, leaves behind capability for future UAS integrated test flights, and allows UAS project an early look at ADS-B operability.
  - Potential for OSD/AFRL Automatic Collision Avoidance Technology (ACAT) cooperation/participation in flight demonstrations
  - ARRA tool and tool interface development
  - ARRA developed surrogate testbed for comm research
  - Potential to leverage FY10 in-guide funding for flight demonstrations

Integrated Tests and Evaluations Objectives (slide 1 of 5)

- **Integrated Flight Test 1 (End of Year 1)**: Demonstrate ADS-B and FMS on Ikhana
  - *Rationale*:
    - Build up for FAA demo of ADS-B and FMS on Predator-B.
    - Provide data to SACA related to the performance and accuracies of ADS-B information for UAS applications
    - Provide early integration of Ikhana Ground Control Station (GCS) with Ames and FAA air traffic simulations.
    - Integrate ADS-B on Ikhana for future flights
  - *Approach*: Fly Ikhana equipped with ADS-B in restricted airspace. Use simulated traffic to feed FMS, which will run in parallel with GCS controlling Ikhana. Evaluate FMS performance in a number of simulated traffic scenarios.
  - *Resources:*
    - FAA-provided FMS
    - Ikhana aircraft, GCS and personnel
    - FAA and ARC sims
    - Restricted airspace

1 UAS
Simulated Traffic
20 Flight Hours
Data for FAA, SACA

Integrated Tests and Evaluations Objectives (slide 2 of 5)

- **Integrated Sim 1 (End of Year 3)**: Evaluate Tactical SA algorithms during nominal operations using human-in-the-loop simulations
  - *Rationale*:
    - Evaluate performance of tactical SA algorithms
    - Evaluate NAS compliant GCS
    - Evaluate performance of CNPC and security protocols
    - Provide build-up to Integrated Flight Test 2 (next slide)
  - *Approach*: Using simulated UAS "flown" by pilots, simulated mixed traffic (UAS and piloted), and simulated ATC "fly" a number scripted test conditions. NAS-compliant GCS features run in parallel with stations controlling the UAS. Simulated CNPC comm and security protocols in conjunction with tactical SA algorithms to evaluate interaction between comm protocols and SA algorithms.
  - *Resources:*
    - SACA-provided SA algorithms
    - PAI-provided GCS features
    - NASA-provided UAS and manned aircraft simulations
    - Comm-provided CNPC and security protocol sims
    - Air Traffic Control Workstations

Simulated UAS
Simulated Traffic
Simulated ATC
Data for SACA, Comm, PAI

Integrated Tests and Evaluations Objectives (slide 3 of 5)

- **Integrated Flight Test 2 (End of Year 3)**: Use two UAS to demonstrate available flight and ground based UAS technologies in preparation for the fully integrated flight demonstration.
  - *Rationale*:
    - Evaluate performance of tactical SA algorithms in relevant environment
    - Evaluate NAS compliant GCS in relevant environment
    - Integrate ADS-B on UAS for future flights
    - Build up to Integrated Flight Test 3 (next slide)
  - *Approach*: Using two ADS-B equipped UAS, fly a number of scripted test conditions. Run the NAS-compliant GCS features in parallel with stations controlling the UAS.
  - *Resources:*
    - SACA-provided SA algorithms
    - PAI-provided GCS features
    - NASA-provided UAS and personnel
    - Restricted airspace

2 UAS
Real UAS Traffic
30 Flight Hours per UAS
Data for SACA, PAI

Integrated Tests and Evaluations Objectives (slide 4 of 5)

- **Integrated Flight Test 3 (End of Year 4)**: Demonstrate available flight and ground based UAS technologies to build up to final flight demonstration (Integrated Flight Test 4).

Specific objectives and details to be developed during phase 1

  - *Rationale*:
    - Evaluate performance of tactical SA algorithms
    - Validate CA requirements
    - Validate NAS compliant GCS
    - Evaluate performance of CNPC and security protocols
    - Provide data for certification case study use
  - *Approach*: Fly multiple UAV systems with multiple piloted aircraft in restricted airspace. The UAS will use features of the prototype NAS compliant Ground Control Station (GCS). One of the manned aircraft will employ the candidate control and non-payload communications (CNPC) protocol and security systems. Both the cockpit and ground personnel will be using the latest Separation Assurance and Collision Avoidance technologies. Nominal and off-nominal air traffic situations will be conducted to exercise the technologies. Simulated air traffic control will be used to evaluate controller workload.
  - *Resources:*
    - NASA-provided manned aircraft
    - NASA-provided UAV systems
    - Air Traffic Control workstations
    - Restricted airspace
    - SAI-provided tactical SA algorithms
    - PAI-provided NAS compliant GCS features
    - Comm-provided CNPC datalink and security systems

3 UAS
2 manned aircraft
30 Flight Hours per aircraft/UAS
Data for SACA, PAI, Comm

Integrated Tests and Evaluations Objectives (slide 5 of 5)

- **Integrated Flight Test 4 (End of Year 5)**: Demonstrate available flight and ground based UAS technologies

Specific objectives and details to be developed during phase 1

  - *Rationale*:
    - Evaluate performance of tactical SA algorithms
    - Validate CA requirements
    - Validate NAS compliant GCS
    - Evaluate performance of CNPC and security protocols
    - Provide data for certification case study use
  - *Approach*: Fly multiple UAV systems with multiple piloted aircraft in restricted airspace. The UAS will use features of the prototype NAS compliant Ground Control Station (GCS). One of the manned aircraft will employ the candidate control and non-payload communications (CNPC) protocol and security systems. Both the cockpit and ground personnel will be using the latest Separation Assurance and Collision Avoidance technologies. Nominal and off-nominal air traffic situations will be conducted to exercise the technologies.
  - *Resources:*
    - NASA-provided manned aircraft
    - NASA-provided UAV systems
    - Air Traffic Control workstations
    - Restricted airspace
    - SAI-provided tactical SA algorithms
    - PAI-provided NAS compliant GCS features
    - Comm-provided CNPC datalink and security systems

3 UAS
1 Surrogate UAS
2 manned aircraft
30 Flight Hours per aircraft/UAS
Data for SACA, PAI, Comm

UAS Integration in the NAS IT&E Milestones

	End of Year 1	End of Year 2	End of Year 3	End of Year 4	End of Year 5
Roadmap	• Draft Roadmap for Federal Public Access	• Gap Analysis and State of the Art Assessment			
SA CA	• Fast time Sim • NowGen NAS • Nominal UAS Ops • Baseline	• Fast time Sim • NextGen NAS • Tactical SA • Nominal UAS Ops	• HiTL Sim • NextGen NAS • Tactical SA • Nominal UAS Ops	• HiTL Sim • NextGen NAS • Tactical SA • Off-nominal UAS Ops • Flight Demo • NextGen NAS • Tactical SA • Nominal UAS Ops	• Flight Demo • NextGen NAS • Tactical SA • Nominal and Off-nominal UAS Ops
PAI			• Develop prototype NAS compliant GCS • Conduct SIMs	• Final GCS Guidelines	• Flight Demo • Prototype GCS/display suite
Comm			• Develop candidate CNPC protocol and security implementation • Conduct Sims	• Fly CNPC suite on T-34C	• Fly CNPC suite in mixed traffic
IT&E	• Ikhana Flight • ADS-B + FMS • Support FAA demo • Integrate GCS + Sims • Prep for future demos	• Specific objectives for Phase II tests	• HiTL Sim • NextGen NAS • Tactical SA • Nominal UAS Ops • NAS compliant GCS • CNPC protocol and security implementation • Flight Demo • NextGen NAS • Tactical SA • NAS compliant GCS	• Flight Demo • NextGen NAS • Tactical SA • Nominal UAS Ops • NAS compliant GCS • CNPC protocol and security implementation • 2 UAS / multiple manned A/C	• Flight Demo • NextGen NAS • Tactical SA • Nominal and Off-nominal UAS Ops • NAS compliant GCS • CNPC protocol and security implementation • 3+ UAS / multiple manned A/C

Summary

- NASA has developed a project plan to address issues related to UAS access to the NAS
  - Plan is being formulated with inputs from our stakeholders
- NASA will work with our stakeholders to develop ConOps and a national roadmap to determine key research technologies and policy issues to enable UAS access to the NAS
- NASA will use ConOps and roadmap to either validate current NASA research investment areas and make any necessary changes to proposed UAS research portfolio
- NASA will conduct integration and testing of key research areas to enable UAS access to the NAS