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

KDP-A for Phase 2 Minimum Operational Performance Standards

Laurie Grindle
Project Manager

September 13, 2016

KDP-A Overview

- During this review, the Project will address the terms of reference (ToR) intent and demonstrate that we are ready to proceed

- The UAS-NAS Project is requesting approval of the following:
  - Technical Challenges
  - Execution of C2 and ACAS Xu partnerships
  - Pursuit of DAA and IT&E partnership plans
  - Execution of near-term FY17 activities

Outline

- UAS Integration in the NAS (UAS-NAS) Overview
- Technical Challenges and Partnership Plans
- Path forward to KDP-C
- KDP-A Summary

Importance of UAS Integration

- According to recent economic assessments[1,2], the unmanned aircraft system (UAS) market is one of the fastest growing segments in the aerospace industry
  - Potential for creating over 100,000 jobs by 2025
  - Translating to over $82 billion in total economic impact

- Several civil/commercial markets are poised to take full advantage of the capabilities UAS offer

• Agriculture Monitoring	• Freight Transport	• Powerline Surveys
• Aerial Imaging/Mapping	• Law Enforcement	• Telecommunications
• Border Surveillance	• Mail/Package Delivery	• News/Sports Coverage
• Disaster Management	• Oil/Gas Exploration	• Traffic Monitoring
• Environmental Monitoring	• Pipeline/Rail Monitoring	• Wildfire Mapping

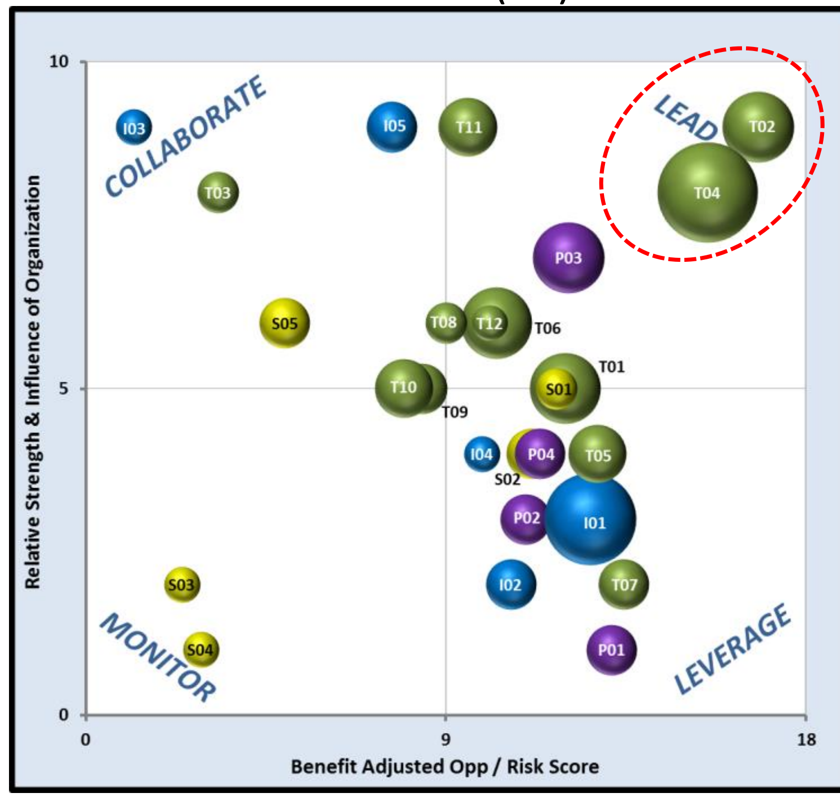
- Unfortunately, the UAS market is not able to achieve this level of growth until the barriers and challenges, currently preventing full integration, are addressed
  - Regulations, Policies and Procedures specific to UAS
  - Enabling Technologies and Standards Development
  - Air Traffic Services and NAS Infrastructure
  - Social Considerations (e.g. Privacy, Security, Noise, Trust)

1. The Economic Impact of UAS Integration in the United States, AUVSI, March 2013
2. World Civil UAS Market Profile & Forecast, Teal Group, 2016

"For every year integration is delayed, the United States loses more than $10B in potential economic impact ($27.6M per day)." *– AUVSI Economic Report 2013*

Importance of NASA Involvement with DAA and C2 Technologies

- UAS Integration and Standards Development align with ARMD's Strategic Plan
- NASA has determined Detect and Avoid (DAA) and Command and Control (C2) are the most significant barriers to UAS integration
- NASA is capable of playing a significant role in addressing UAS airspace integration challenges
  - NASA's long-standing history assisting the FAA with complex aviation challenges
  - NASA involvement instills confidence in industry standards development activities
- NASA held in high regard by others in UAS community due to our:
  - Prior research and contribution to standards development
  - Existing leadership role in ongoing efforts and working groups
  - Ability to leverage previous assets used for Phase 1 MOPS



Full Integration study identified NASA as being well positioned to Lead the DAA (T02) and C2 (T04) airspace integration challenges

NASA well positioned to lead research addressing most significant barriers, DAA and C2, to UAS integration

Importance of Developing DAA and C2 Standards

- The FAA's *UAS CONOPS* and *Roadmap* establish the **vision** and define **the path forward** for safely integrating civil UAS operations into the NAS
  - These documents establish the importance of standards development; explicitly DAA and C2 standards
    - DAA Foundational Challenge: Sense & Avoid vs. See & Avoid
    - C2 Foundational Challenge: Robust and secure communication links

Federal Aviation Administration

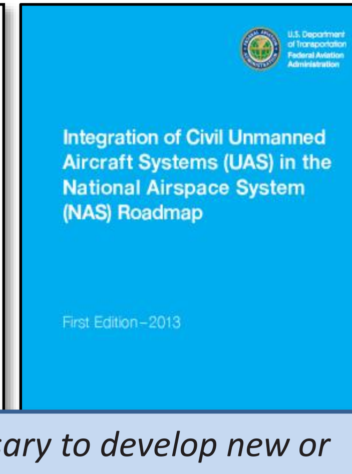
September 28, 2012

Integration of Unmanned Aircraft Systems into the National Airspace System

Concept of Operations

V2.0

Concurrence:



U.S. Department of Transportation Federal Aviation Administration

Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap

First Edition–2013

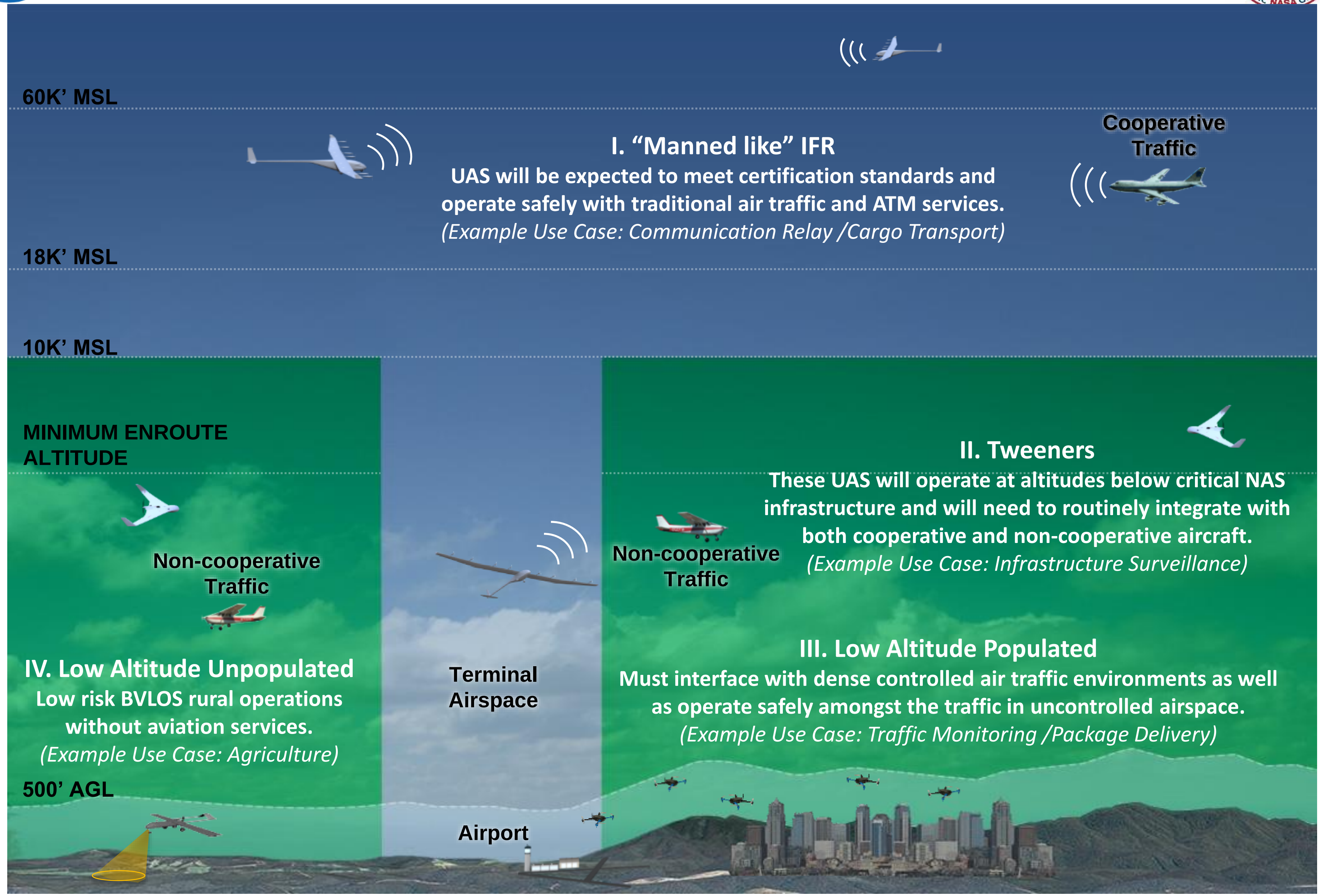
> *"Therefore, it is necessary to develop new or revised regulations/ procedures and operational concepts,* ***formulate standards****, and promote technological development that will enable manned and unmanned aircraft to operate cohesively in the same airspace.* ***Specific technology challenges include two critical functional areas:***
>
> ***1. Detect and Avoid (DAA) capability***
>
> ***2. Control and Communications (C2) system performance requirements"***
>
> \- FAA Integration of Civil UAS in the NAS Roadmap, First Edition 2013

- Standards are essential for multiple stakeholders:
  - Regulators
  - UAS Operators
  - UAS Manufacturers
  - Avionics and Service Providers

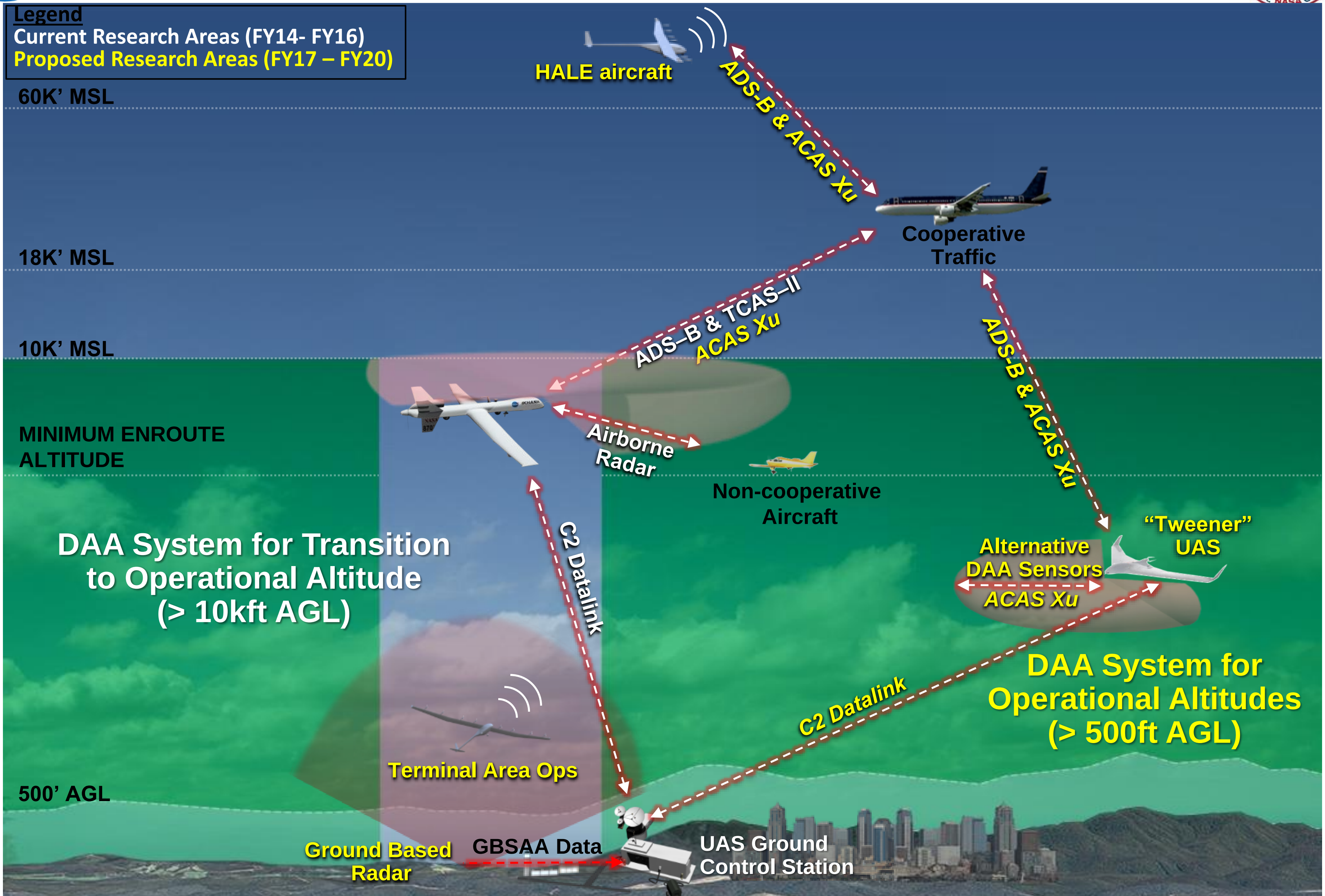
- RTCA SC-203 was, and SC-228 now is, chartered by the FAA to establish UAS DAA and C2 Standards

Once the RTCA SC-228 ToR deliverables are approved and their requirements fulfilled, the FAA should be able to eliminate most of the major DAA and C2 barriers for integration.

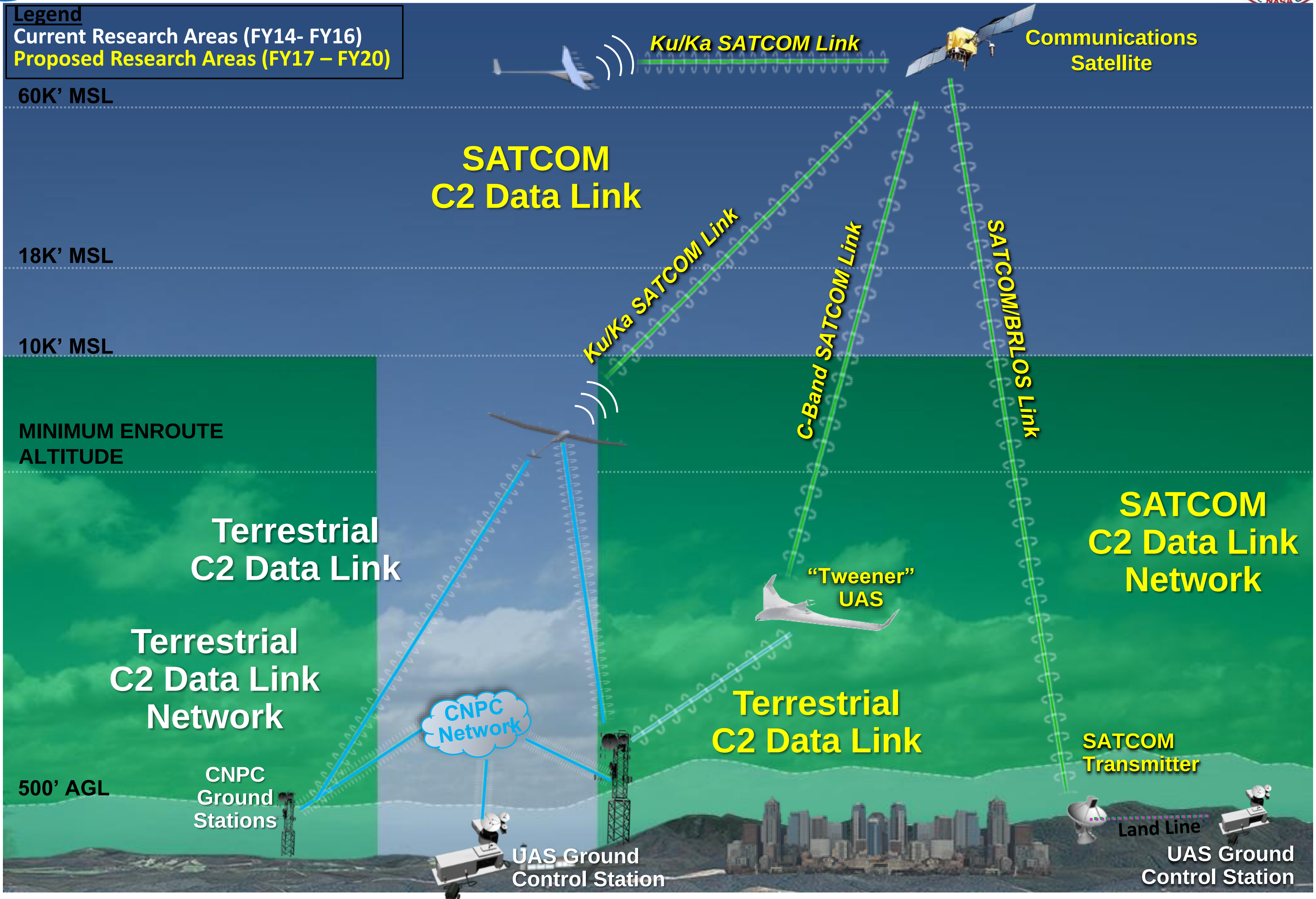
Emerging Commercial UAS Operational Environments (OE)



DAA Operational Environments

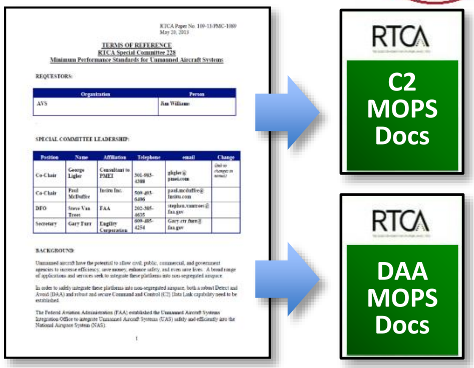


C2 Operational Environments



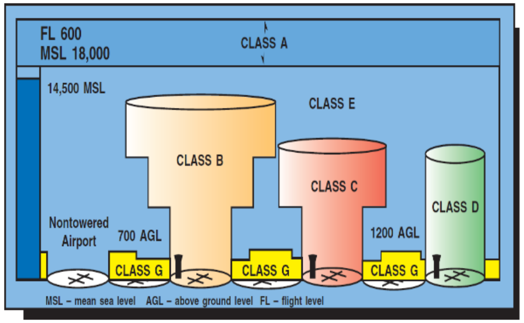
RTCA SC-228 MOPS Terms of Reference

- RTCA SC-228 Terms of Reference (ToR) defined a path forward to develop Minimum Operational Performance Standards (MOPS)
  - Phase 1 MOPS were addressed by UAS-NAS (FY14 – FY16) Portfolio
  - Phase 2 MOPS included in the original ToR, but had several TBDs
    - ToR development team established to ensure DAA & C2 scope broad enough to fully enable the operating environments relevant UAS were expected to leverage (e.g. Manned Like IFR and Tweeners)



RTCA SC-228 ToR

- Phase 2 MOPS ToR Scope
  - C2: Use of SATCOM in multiple bands and terrestrial extensions as a C2 Data Link to support UAS and address networking interoperability standards for both terrestrial and satellite systems
  - DAA: Extended UAS operations in Class D, E, and G, airspace, and applicability to a broad range of civil UAS capable of operations Beyond Visual Line of Sight (BVLOS)



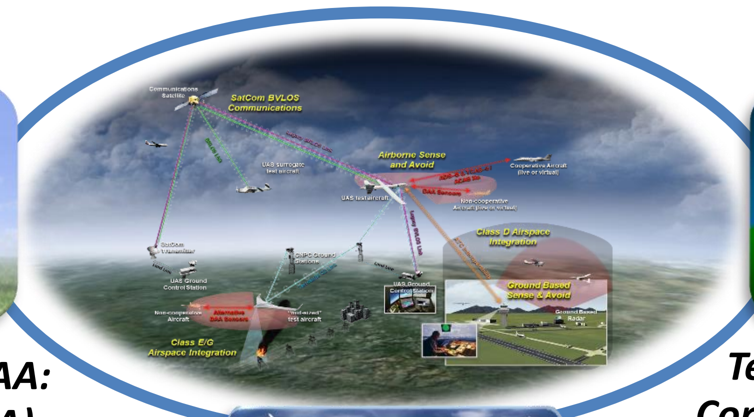
- SC-228 Final Documents

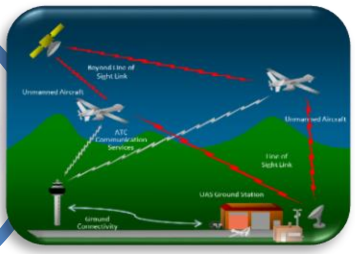
Phase 1 (To Be Published 2016)	Phase 2	
• C2 Terrestrial Datalink MOPS	• C2 SATCOM & Network MASPS (Oct 2017 & Jan 2019)	• Ground Based Primary Radar MOPS & DAA MOPS Rev A (Sep 2019)
• DAA MOPS	• C2 SATCOM Data Link MOPS (Jul 2019*)	• Non-Cooperative Sensor MOPS & DAA MOPS Rev B (Sep 2020)
• DAA Air to Air Radar MOPS	• C2 Terrestrial Data Link MOPS Rev A (Jul 2020)	

* **Date under discussion within RTCA SC-228**

Project Goal, Research Themes, & Technical Challenges
UAS-NAS Project

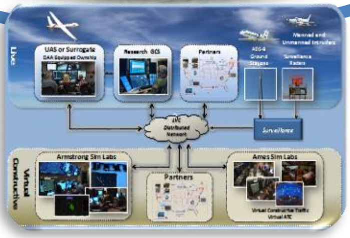
Goal: Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating Unmanned Aircraft Systems into the National Airspace System





Technical Challenge-DAA: Detect and Avoid (DAA)

Technical Challenge-C2: Command and Control (C2)



Technical Challenge-ITE: Integrated Test & Evaluation (IT&E)

ARMD Strategic Plan Flow Down to UAS-NAS Project

AERONAUTICS STRATEGIC THRUST

- **Thrust 1:** Safe Efficient Growth in Global Operations
- **Thrust 6:** Assured Autonomy for Aviation Transformation

AERONAUTICS OUTCOME

- **Outcome (2015 – 2025):** ATM+1 Improved NextGen Operational Performance in Individual Domains, with Some Integration Between Domains
- **Outcome (2015 – 2025):** Initial Introduction of aviation systems with bounded autonomy, capable of carrying out function-level goals

AERONAUTICS Research Theme

- Airspace Operations Performance Enablers
- Implementation and Integration of Autonomous Airspace and Vehicle Systems
- Testing and Evaluation of Autonomous Systems

AERONAUTICS Overarching Technical Challenge

- Develop Operational Standards for UAS in NAS
- 4B. Select, develop, and implement applications of autonomy that are compatible with existing systems

  4C. Develop framework for co-development of policies, standards, and regulations with development and deployment of increasingly autonomous systems
- 5B. Test, evaluate & demonstrate selected small-scale applications of autonomy

UAS-NAS *Technical Challenges*

TC-C2: Command & Control

TC-DAA: Detect and Avoid

TC-ITE: Integrated Test & Evaluation

Primary Mapping
Secondary Mapping

Outline

- UAS Integration in the NAS (UAS-NAS) Overview
- Technical Challenges and Partnership Plans
  - Command and Control (C2)
  - Detect and Avoid (DAA)
  - Integrated Test and Evaluation (IT&E)
- Path forward to KDP-C
- KDP-A Summary

Technical Challenge Background

- Technical Challenge Section Content
  - Technical Challenge Wording
  - Technical Challenge Technologies
    - Related NASA research, State of the art (SOA), and advancement of the SOA through proposed research
  - Technical Challenge Research Summary
    - Proposed research areas and near term activities to be started on or before Oct 1
    - Varying stages of development within the TCs
  - Partnership strategy and plans
    - C2 and IT&E have partnerships ready to execute
    - DAA is working with IT&E to refine requirements and partnership selection paths
  - *Data Deleted*

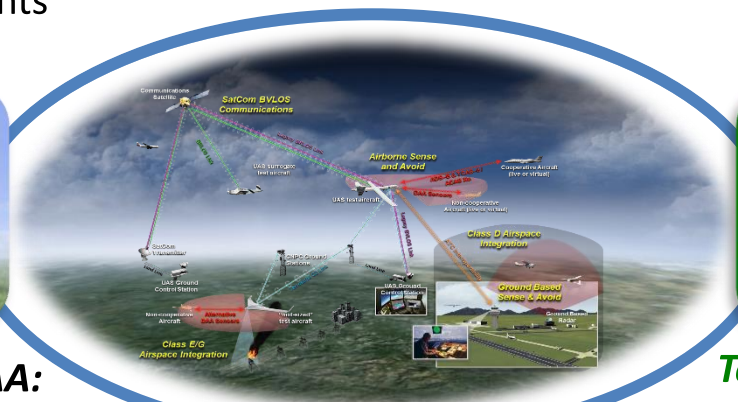
TC-C2: Command and Control

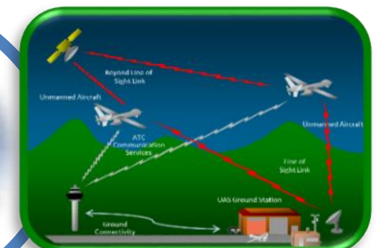
Research Theme Thrust 1 – Airspace Operations Performance Enablers

Research Theme Thrust 6 – Implementation and Integration of Autonomous Airspace and Vehicle Systems

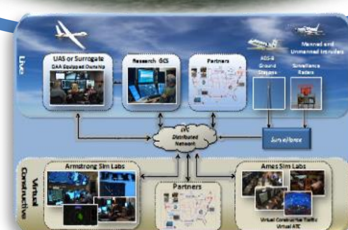
TC-C2 – Develop, mature, and provide research findings from analysis, simulations, flight tests, and validation of SC-228 Phase 2 Command and Control (C2) Minimum Operational Performance Standards (MOPS) that will enable Satellite and Terrestrial Communication System Architectures compliant with allocated spectrum requirements

Technical Challenge-DAA: Detect and Avoid (DAA)





Technical Challenge-C2: Command and Control (C2)



Technical Challenge-ITE: Integrated Test & Evaluation (IT&E)

C2 Overview

State of the Art:

- NASA and partners (i.e. RTCA, Rockwell Collins, etc.) have developed and written standards for a robust and secure terrestrial C2 capability in internationally protected aviation spectrum
- The performance standards development must continue on to fully enable terrestrial architectures, and critical satellite communication technologies

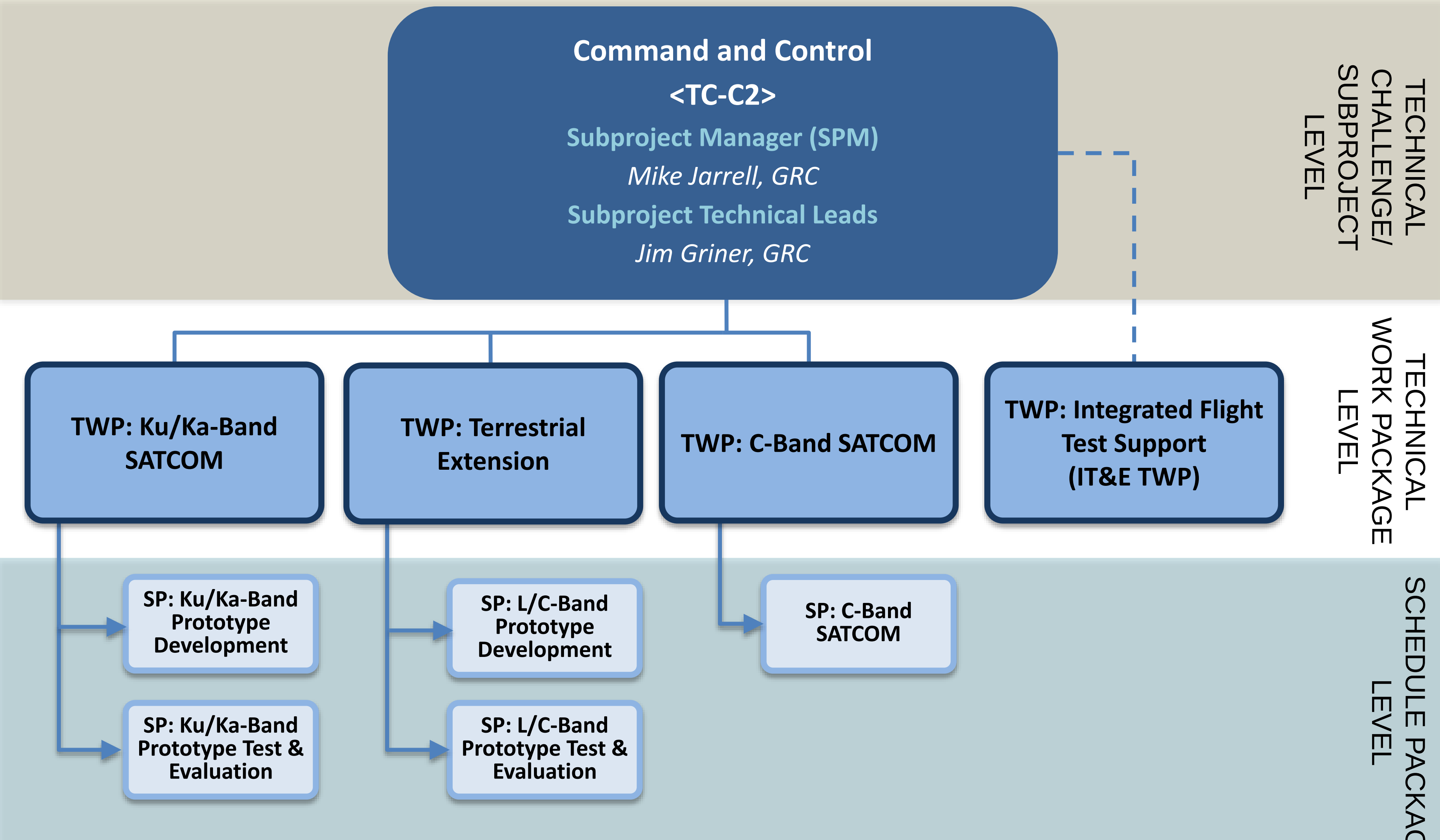
Related NASA Work:

- Developed and flight tested radios (65 mission flights, ~200 hours of data collection, 12 locations)
- Led national and international efforts on Terrestrial C2, and has significant expertise in upcoming SATCOM technologies

TC Advancement:

- A broad set of architectures will be developed and standardized allowing industry to fly their aircraft with well characterized high reliability C2 links

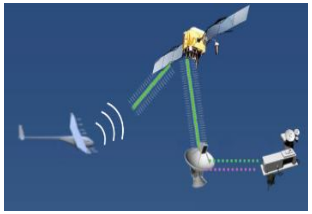
C2 Subproject Structure



- **TWP: Technical Work Package**
- **SP: Schedule Package**

C2 Technical Plan

TWP: Ku/Ka-Band SATCOM

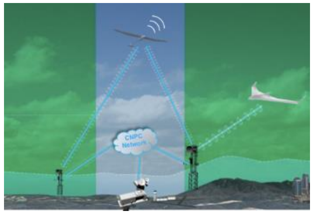


Develop requirements for a SATCOM link between a UAS and it's GCS that: supports the UA performance in the NAS, ensures that the pilot maintains a threshold level of control of the aircraft, and is robust to security and technological issues

Near-Term Activities Include:

- Participation in RTCA SC-228 C2 White Paper development, SOA analysis, and Gap Analysis
- Initiate Cooperative Agreement*, Preliminary Design, Lab and Aircraft Test Upgrades, System Architecture Study, Initial System Interface Development

TWP: Terrestrial Extension



Develop requirements for a Terrestrial link, focused on broader flight regimes, that: supports the UA performance in the NAS, ensures the pilot maintains a threshold level of control of the aircraft, and is robust to technological issues

Near-Term Activities Include:

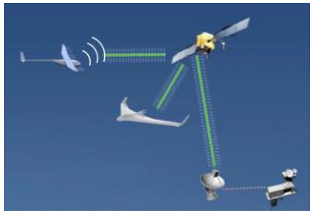
- Establish Cooperative Agreement*, Trade Study, Baseline Specifications, Preliminary Interface Development, Lab and Aircraft Test Gap Analysis

*** Partnership Plans will be addressed separately**

C2 Technical Plan

TWP: C-Band SATCOM

Generate design documentation for a C-Band SATCOM system through a series of studies to develop: initial design parameters of airborne and ground station equipment, a preliminary payload design, and assess the feasibility of an operational C-Band satellite-based CNPC system

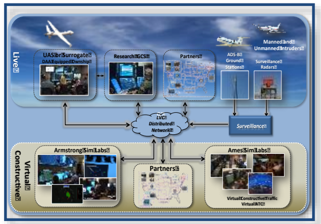


Near-Term Activities Include:

- SATCOM Survey, Trade Study, System Design, Cost/Benefit Assessment

TWP: IT&E Support

Support the IT&E Technical Challenge for Integrated Flight Tests equipped with equipment developed for Phase 1 C2 MOPS



Near-Term Activities Include:

- Support TWP Content Decision as required

C2 Data Link
Partnership TWP Planning

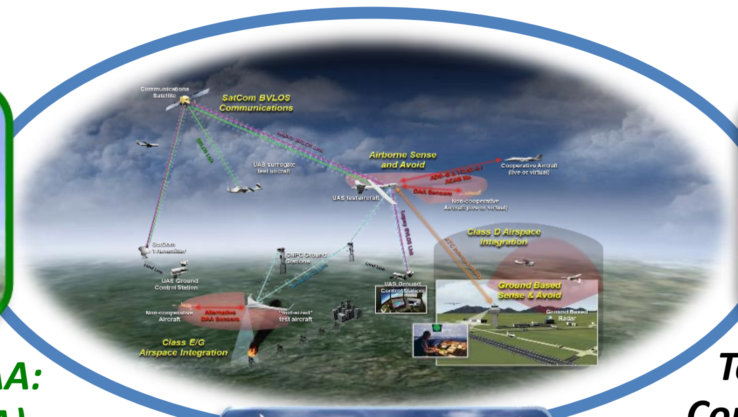
- Data Removed

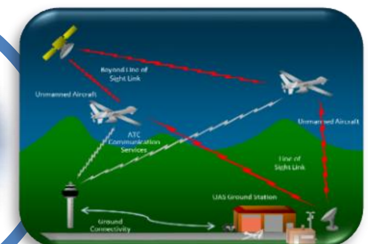
C2 Partnership Strategy

- Data removed

TC-DAA: Detect and Avoid

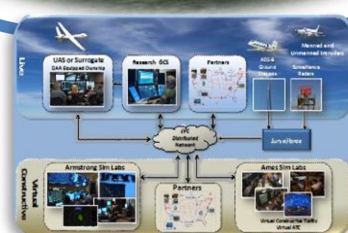
Research Theme Thrust 1	– Airspace Operations Performance Enablers
Research Theme Thrust 6	– Implementation and Integration of Autonomous Airspace and Vehicle Systems
TC-DAA	– Develop, mature, and provide research findings from analysis, simulations, flight tests, and validation of SC-228 Phase 2 Detect and Avoid (DAA) Minimum Operational Performance Standards (MOPS) that will enable a broader range of IFR-like UAS BVLOS Operations by providing technology to safely “See and Avoid” traffic in the NAS





Technical Challenge-DAA: Detect and Avoid (DAA)

Technical Challenge-C2: Command and Control (C2)



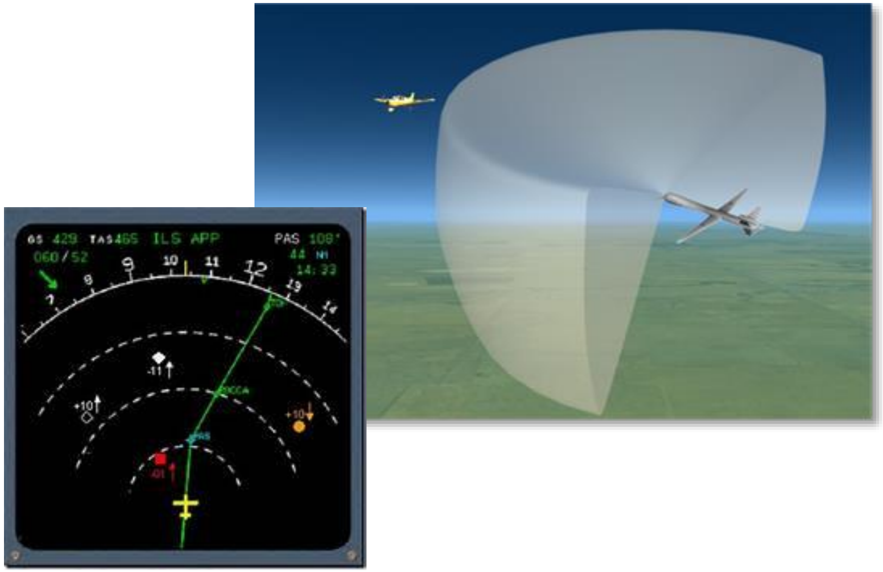
Technical Challenge-ITE: Integrated Test & Evaluation (IT&E)

DAA Overview

State of the Art:

- NASA and partners (i.e. RTCA, General Atomics, Honeywell, FAA TCAS etc.) have developed and standardized a DAA capability that be leveraged as an alternative means of compliance to “see and avoid”

- Additional DAA performance standards are required to fully enable operational use cases in terminal areas and for a vehicles with lower performance capabilities



Related NASA Work:

- NASA has performed simulations, developed and tested a DAA system, led national efforts on DAA, and has significant expertise in upcoming standards for ground and airborne sense and avoid

TC Advancement:

- DAA systems developed and standardized that are applicable to broad set of UAS that will fly in the NAS

DAA Subproject Structure

TECHNICAL CHALLENGE/ SUBPROJECT LEVEL

Detect and Avoid
<TC-DAA>
Subproject Manager (SPM)
Jay Shively, ARC
Subproject Technical Leads
Confesor Santiago, ARC, Tod Lewis, LaRC, TBD, ARC

TECHNICAL WORK PACKAGE LEVEL

SCHEDULE PACKAGE LEVEL

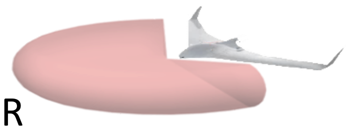
- **TWP: Alternate Surveillance Requirements**
  - SP: TBD
  - SP: TBD
  - SP: TBD
- **TWP: Well Clear Alerting Requirements**
  - SP: TBD
  - SP: TBD
  - SP: TBD
- **TWP: ACAS Xu**
  - SP: TBD
  - SP: TBD
  - SP: TBD
- **TWP: External Collaborations**
  - SP: TBD
- **TWP: Integrated Events**
  - SP: TBD
  - SP: TBD
  - SP: TBD

- **TWP: Technical Work Package**
- **SP: Schedule Package**

DAA Technical Plan

TWP: Alternate Surveillance Requirements

Supports the development of MOPS for alternative Phase 1 surveillance systems. The work may include ground-based radar, as well as low-cost, low-power cooperative and non-cooperative sensors, e.g. "mini-ADS-B", electro-optical, and LIDAR

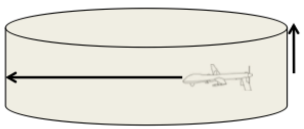


Near-Term Activities Include:

- CONOPS development, requirements studies, sensor model integration, and fast-time simulation

TWP: Well Clear/Alerting Requirements

Fast-time simulations and human-in-the-loop simulations to refine the well clear definition and alerting requirements for the operational environments specific to P2 MOPS



Near-Term Activities Include:

- Develop CONOPS and requirements for well clear interoperability
- Define well clear, algorithms, airspace, aircraft performance, sensor assumptions, etc., leveraging fast-time simulation

DAA Technical Plan

TWP: ACAS Xu

Supports the development of minimum operational performance standards for integrated Collision Avoidance (CA; ACAS Xu) and DAA alerting and guidance displays and algorithms

Near-Term Activities Include:

- Interoperability workshop and CONOPS definition for ACAS Xu
- Part Task Sims (i.e. HITLs) planning to assess interoperability and pilot interfaces

TWP: External Collaborations

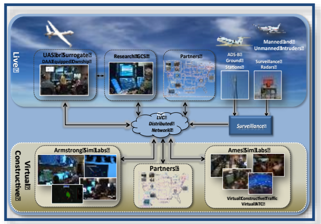
Attend and help lead SC-228 Phase 2 DAA planning, support development of the Phase 2 MOPS deliverables

Near-Term Activities Include:

- Attend and help lead SC-228 Phase 2 DAA planning
- Support development of the white paper for Phase 2

TWP: Integrated Events

Utilize the UAS-NAS cross-center research, simulation and flight test capabilities in order to support key verification and validation activities for the Phase 2 DAA MOPS



Near-Term Activities Include:

- Provide high level flight test requirements to IT&E for ACAS Xu, FT5, and FT6

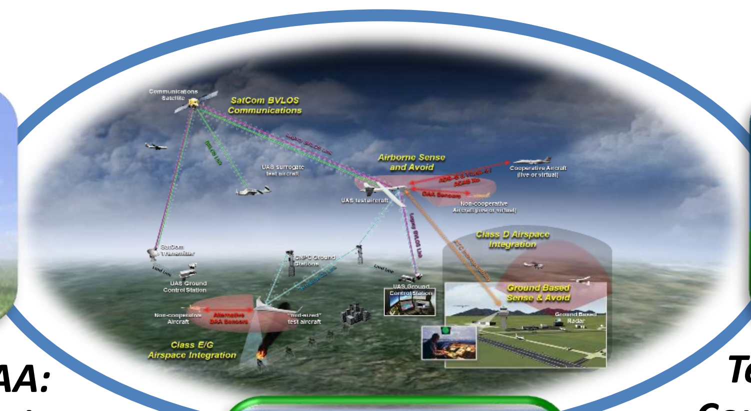
DAA Partnership Strategy
(Joint with IT&E)

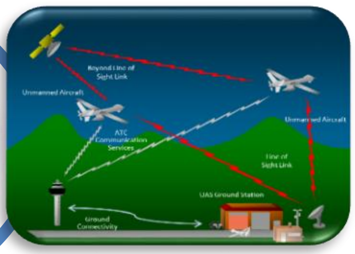
- *Data Removed*

TC-ITE: Integrated Test & Evaluation

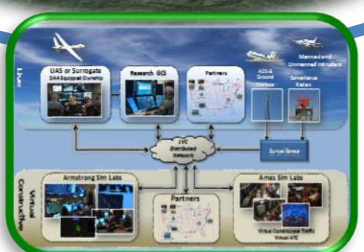
Research Theme Thrust 1	– Airspace Operations Performance Enablers
Research Theme Thrust 6	– Testing and Evaluation of Autonomous Systems
TC-ITE	– Implement UAS simulation and flight test environments that will enable development, verification and validation of integrated DAA and C2 technologies on UAS

Technical Challenge-DAA: Detect and Avoid (DAA)





Technical Challenge-C2: Command and Control (C2)



Technical Challenge-ITE: Integrated Test & Evaluation (IT&E)

MOPS V&V Contribution by IT&E

- **Verification & Validation (V&V) testing of DAA system**
  - Integrate DAA systems consistent with MOPS development and research activities. Leverage State of the Art UAS, architectures, and sensors to perform flight tests that stress the DAA system and validate necessary research elements.

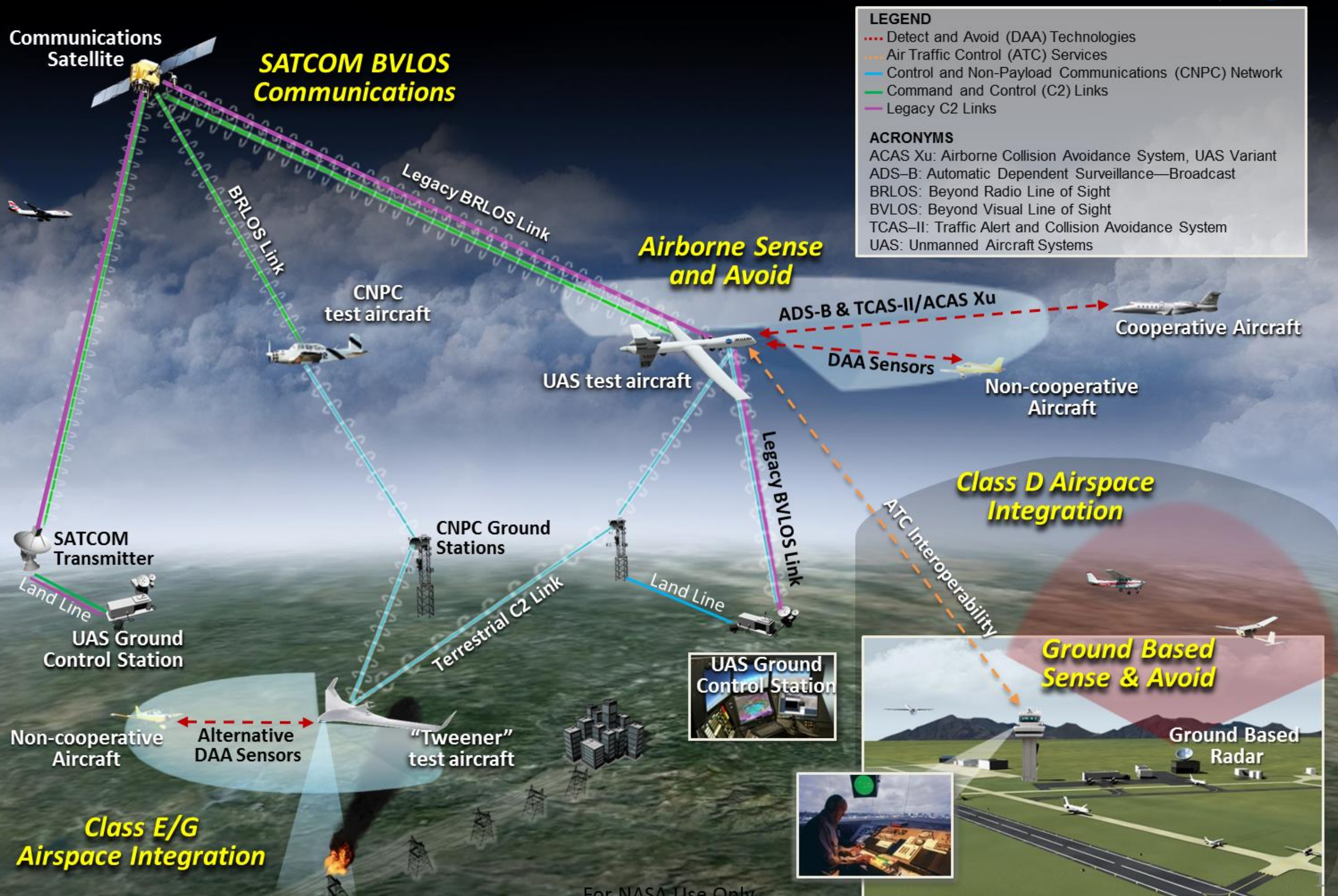
- **Integrated Testing of DAA and C2 systems**
  - Integrate DAA and C2 technology systems consistent with P1 and P2 MOPS development efforts. Leverage integration and test results to ensure aircraft level functional and operational performance criteria can be met. Leverage Integrated tests to enable UAS operational approval and certification.

RTCA Minimum Operational Performance Standards (MOPS) Drafting Guide

"Aircraft Operational Performance Characteristics: When equipment is designed and manufactured to meet these MOPS, and it is properly installed in an aircraft in accordance with applicable installation and operational approval guidance and regulations, it is expected that <u>all aircraft level functional and operational performance criteria will be met</u>"

Performance Standards V&V Operational View

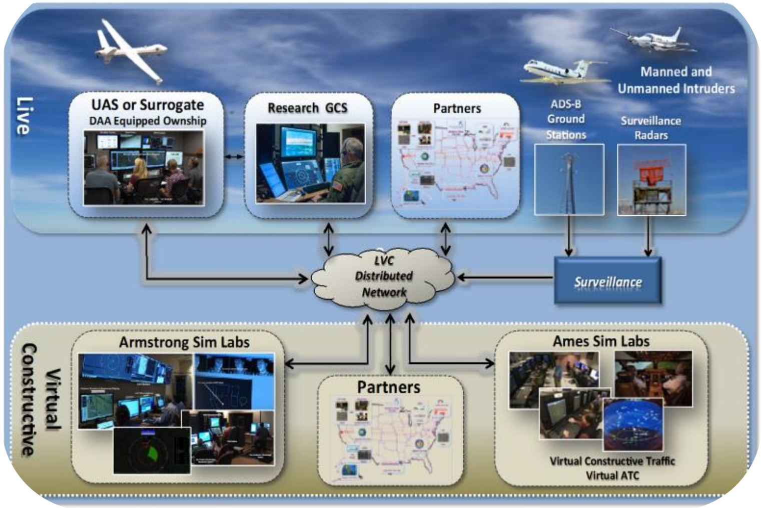
National Aeronautics and Space Administration



IT&E Overview

State of the Art:

- NASA assets such as Ikhana, the LVC-DE, and CNPC radios were built for Phase 1 MOPS. Future systems incorporate technologies developed to support other SAA efforts (e.g. Army GBSAA, industry low-SWaP airborne sensor development)



Related NASA Work:

- The NASA UAS-NAS IT&E subproject played a key role in validating the Phase 1 MOPS through M&S and flight test including ~ 700 DAA system encounters performed

TC Advancement:

- Simulation/flight systems and infrastructure for development, verification and validation of MOPS

- Rigorous NASA safety processes applied against SOA aircraft and technology systems in order to conduct highly complex testing

IT&E Subproject Structure

TECHNICAL CHALLENGE/ SUBPROJECT LEVEL

Integrated Test & Evaluation
<TC-ITE>
Subproject Manager (SPM)
Heather Maliska, AFRC
Subproject Technical Leads
Sam Kim, AFRC, Jim Murphy, ARC

TECHNICAL WORK PACKAGE LEVEL / **SCHEDULE PACKAGE LEVEL**

- **TWP: Integration of Technologies into LVC-DE**
  - SP: LVC-DE e-Client Integration
  - SP: LVC-DE Client Integration
  - SP: TBD
- **TWP: Simulation Planning & Integration**
  - SP: TBD
  - SP: TBD
  - SP: TBD
- **TWP: LVC-DE Infrastructure Sustainment**
  - SP: LVC-DE Improvements
  - SP: TBD
- **TWP: Integrated Flight Test**
  - SP: ACAS Xu FT2
  - SP: No Chase COA
  - SP: TBD
  - SP: TBD

- **TWP: Technical Work Package**
- **SP: Schedule Package**

IT&E Technical Plan

TWP: Integration of Technologies into LVC-DE

Development and integration of DAA and C2 technologies, primarily focusing on DAA subproject technologies. Also includes external partner integration and associated cyber security considerations

Near-Term Activities Include:

- LVC-DE Client Integration - Integrate ACAS into LVC-DE. Update LVC ICD to support ACAS flight messaging
- Systems Engineering - Document LVC system requirements. Develop simulation ConOps

TWP: Simulation Planning & Integration

Support for the planning and conduct of the DAA HITLs, document objectives and requirements, trace system level requirements, and develop V&V test matrix

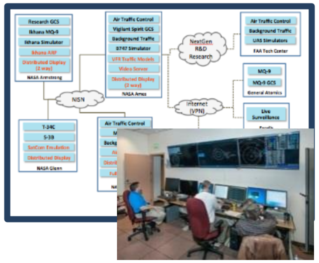
Near-Term Activities Include:

- Coordinate with DAA to determine plan for Phase 2 simulations

IT&E Technical Plan

TWP: LVC-DE Infrastructure Sustainment

LVC-DE infrastructure sustainment and continuous improvement. This work includes effort to maintain connectivity to our existing partners and software clients.

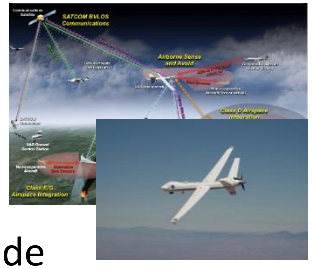


Near-Term Activities Include:

- Investigate potential LVC improvements based on simulation and flight lessons learned

TWP: Integrated Flight Test

Integrate the individual technology development simulation and flight test objectives and requirements into executable tests. Conduct flight tests. Collect, archive, and distribute test data

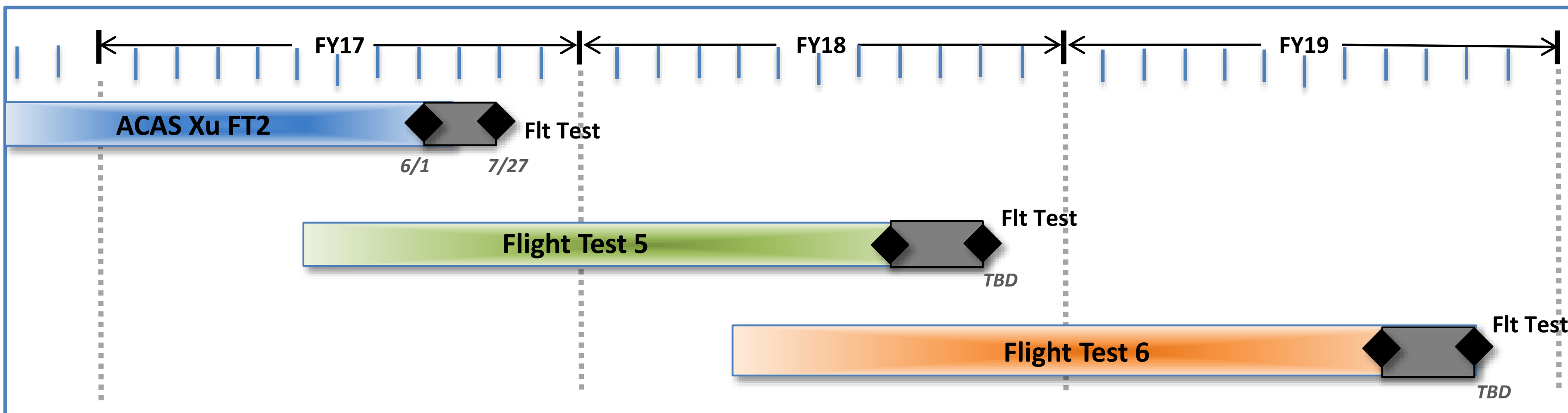


Near-Term Activities Include:

- FT5 and FT6 Trade Study – Work with DAA to define requirements based on trade study results
- ACAS Xu FT2 – Conduct PDR/CDR. Complete GA and FAA SAA. Begin aircraft modifications

Integrated Flight Test Progression

- The IT&E subproject will perform flight tests leveraging technology progressions to meet project objectives by the final flight test in FY19
- ACAS Xu Flight Test 2 (FT2)
  - Necessary to ensure timely development of ACAS Xu technology in support of DAA system development
  - Ensures NASA has appropriate Collision Avoidance (CA) hardware, software, and partnerships in place for future flight test efforts
- NASA Flight Test 5 (FT5) and Flight Test 6 (FT6)
  - Leverages cross subproject DAA and IT&E partnership strategy to progressively test DAA technologies relevant to the project portfolio
  - Developed to further P2 MOPS deliverables according to industry state of the art
  - Implements Program and Project expectations for integrated DAA and C2 flight test executed by IT&E



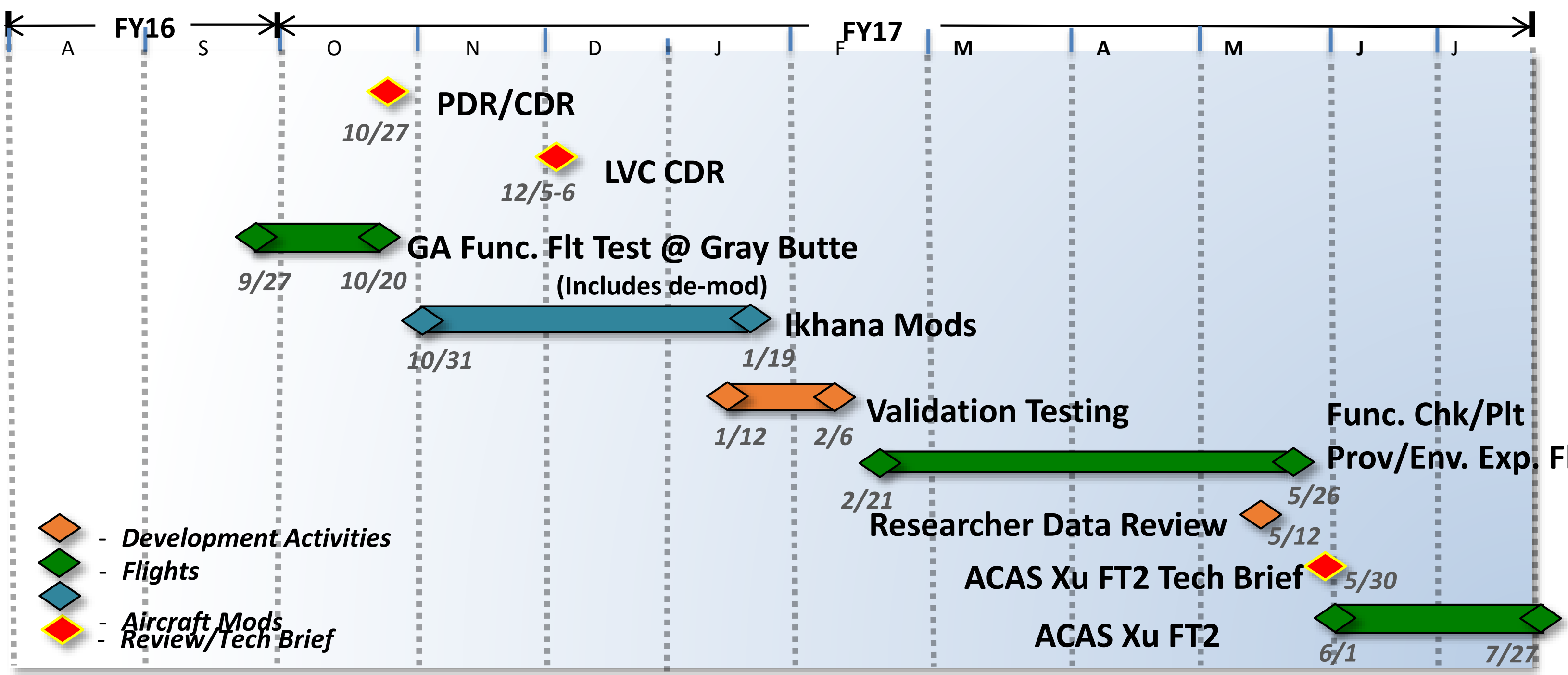
IT&E ACAS Xu
Partnership TWP Planning

Partnership TWPs Titles:

Integration of Technologies into LVC-DE Integrated Flight Test

ACAS Xu Partnership TWP Attributes:

1. Have detailed technical schedules
2. Well developed partnership planning efforts
3. Leverage P1 MOPS related partnerships or partnership strategies



*** Notional Dates for Subproject Formulation**

ACAS Xu Partnership Strategy

- *Data Removed*

FT5 and FT6 Integrated Test Strategy

Approach to define FT5 and FT6

- The full trade space of DAA development and Flight Test options will be assessed as part of the Cost, Benefit, Risk assessment to determine the final partnership strategy
  - IT&E is working closely with DAA to evaluate 50+ RFI inputs to select best partners and strategy
- Flight test definition based on the outcome of risk analysis and research requirements for DAA and C2
  - Document DAA research objectives and requirements
  - Build LVC infrastructure
  - Conduct DAA simulation leading to Flight Test

Integrated Test Strategy

- Project desires all TCs and technology systems in the Project portfolio have appropriate TC robustness, and are able to be taken to flight
  - Example: Elements for fully integrated flight test include; airspace, full and mid-size UAS, multiple DAA sensor suites (GBSAA and alternative airborne), ACAS Xu, Research Ground Control Station, displays, P2 SATCOM, P2 Terrestrial C2, P1 Terrestrial C2
- The project will assess the options for integrated flight test and incorporate it into KDP-C
  - Anticipate only P1 MOPS DAA and C2 systems will be integrated into testing due to P2 MOPS technology development cycles and project cost/schedule considerations

IT&E Partnership Strategy
(Joint with DAA)

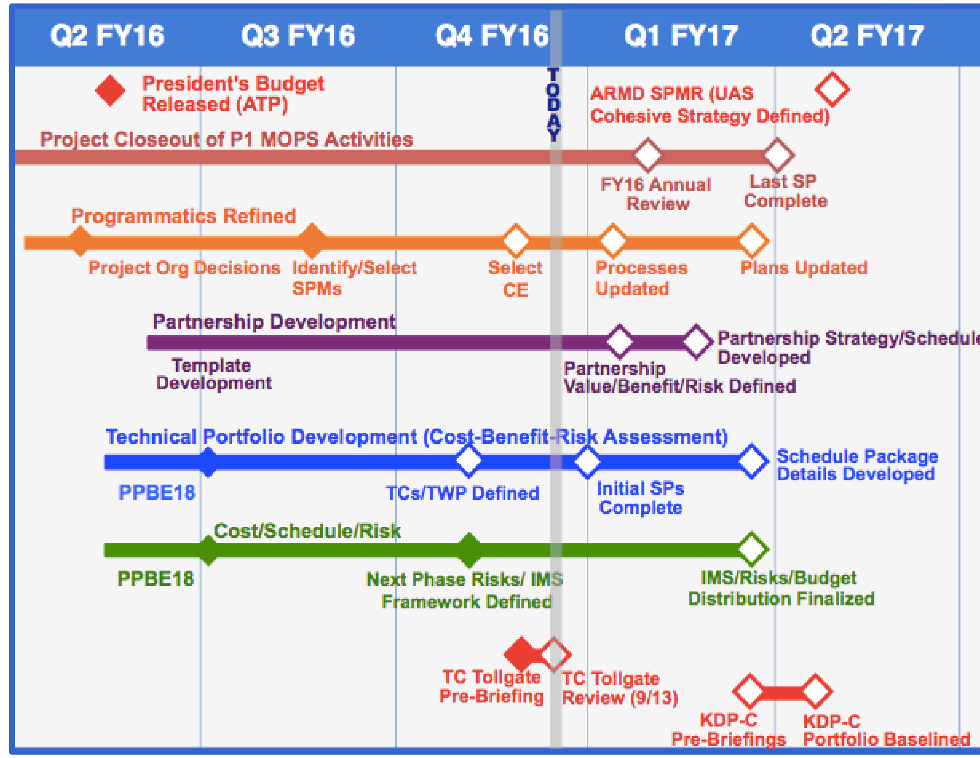
- Data Removed

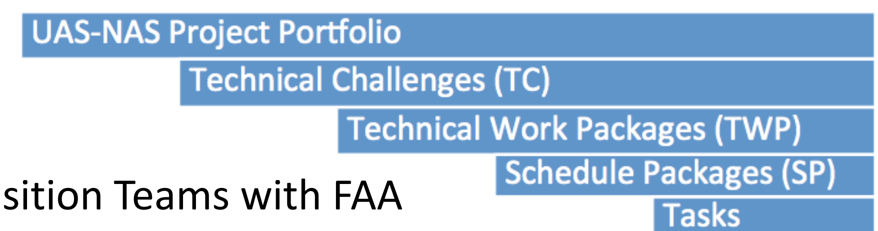
Outline

- UAS Integration in the NAS (UAS-NAS) Overview
- Technical Challenges and Partnership Plans
- Path forward to KDP-C
- KDP-A Summary

Path to KDP-C

- Project Management
  - Demonstrated rigorous processes in previous Project phases
    - Review/Update Project Processes
- Partnerships
  - Execute C2 partnerships
  - Execute ACAS Xu partnerships
  - Develop DAA & ITE partnership plans
- Technical Portfolio Development
  - Perform TWP Content Decision Points (Cost/Benefit/Risk)
  - Develop Technical Schedule Packages
    - Update Integrated Master Schedule





- Other activities occurring in this time frame
  - Participate in development of Research Transition Teams with FAA
  - Will develop proposals on other potential research activities for consideration at SPMR
  - Will assess our portfolio against the UAS Cohesive Strategy once it's defined

Outline

- UAS Integration in the NAS (UAS-NAS) Overview
- Technical Challenges and Partnership Plans
- Path forward to KDP-C
- KDP-A Summary

KDP-A Summary

- UAS Integration in the NAS Project has:
  - Developed Technical Challenges that are crucial to UAS integration, aligned with NASA’s Strategic Plan and Thrusts, and support FAA standards development
  - Demonstrated rigorous project management processes through the execution of previous phases
  - Defined Partnership Plans
  - Established path to KDP-C

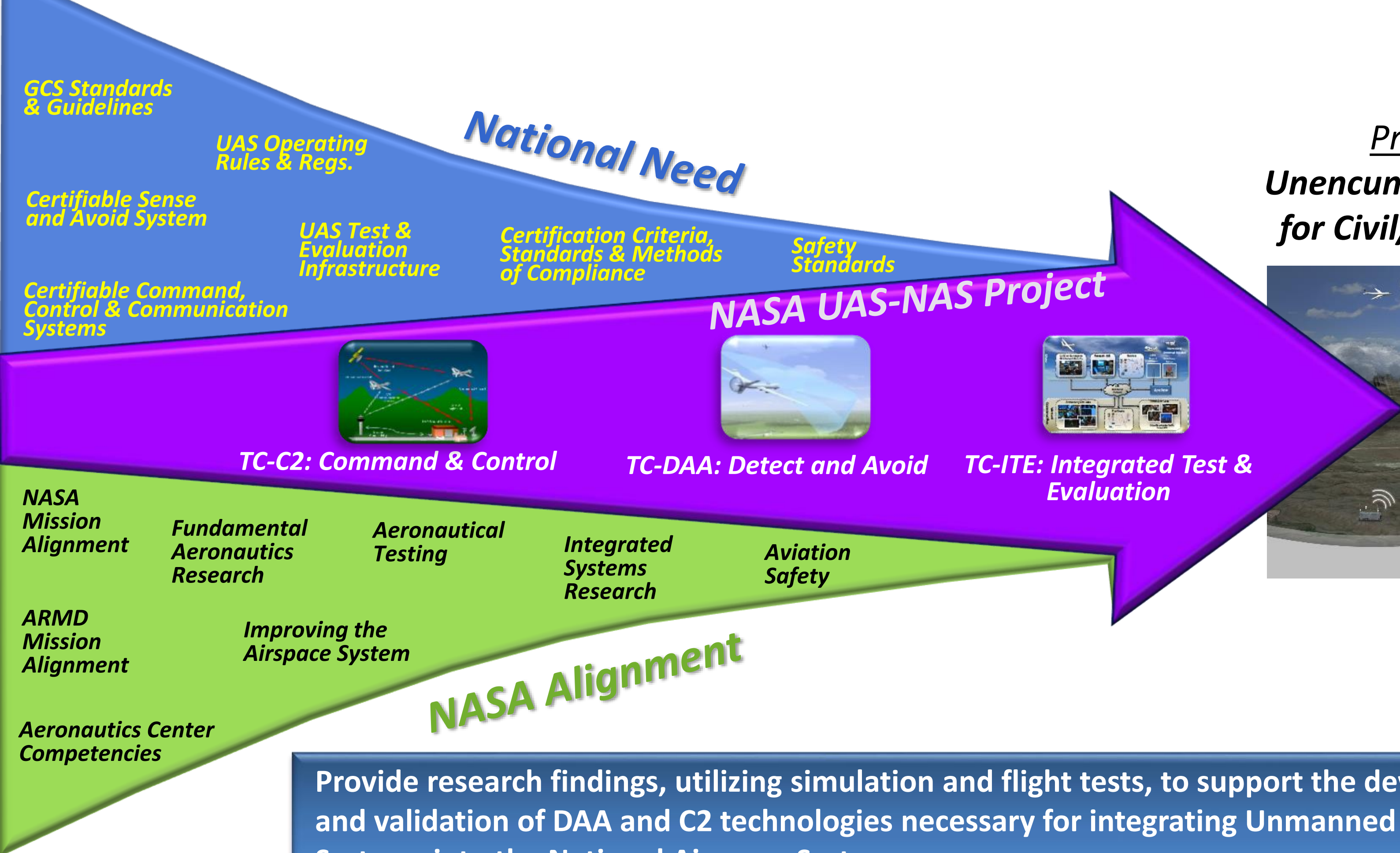
- Request approval of Technical Challenges, execution of partnerships and plans, and execution of near-term FY17 activities

Project is ready to proceed towards KDP-C

Backup

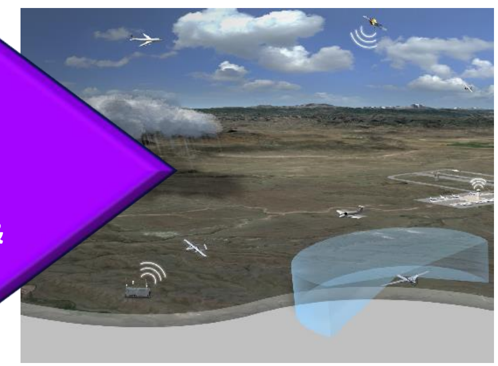
Developing the Project

There is an increasing need to fly UAS in the NAS to perform missions of vital importance to National Security and Defense, Emergency Management, and Science. There is also an emerging need to enable commercial applications such as cargo transport (e.g. FedEx)



Project Focus:

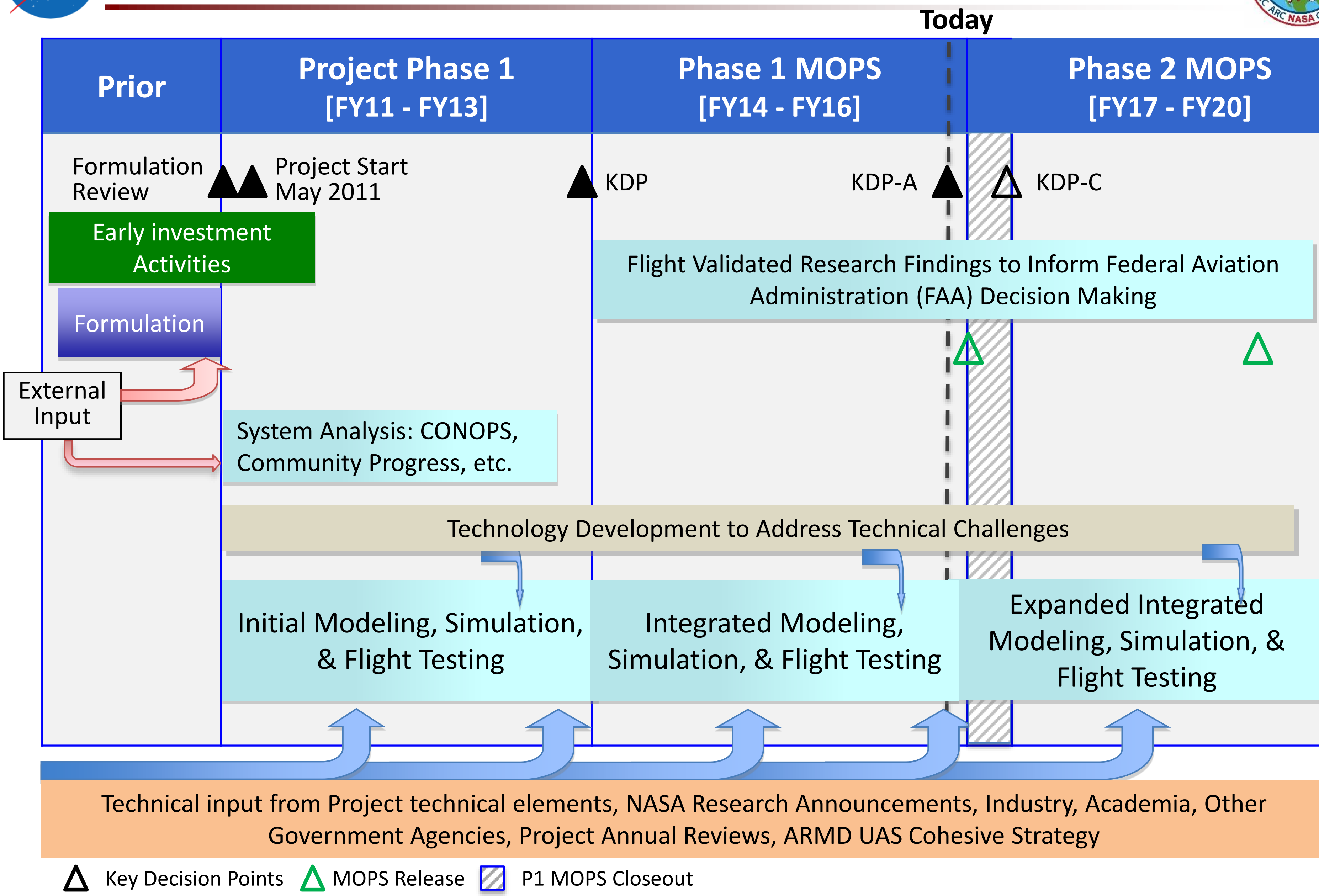
Unencumbered NAS Access for Civil/Commercial UAS



Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating Unmanned Aircraft Systems into the National Airspace System

UAS-NAS Project Lifecycle

Timeframe for impact: 2015 - 2025



UAS-NAS Phase 2 MOPS Organization Structure

PROJECT OFFICE LEVEL

Project Leadership

Project Manager (PM)	Laurie Grindle, AFRC
Deputy PM	Robert Sakahara, AFRC
Deputy PM, Integration	Davis Hackenberg, AFRC
Chief Engineer	TBD, TBD

Project Support: Project Planning & Control

Lead Resource Analyst	April Jungers, AFRC
Resource Analysts	Winter Preciado, AFRC
	Carmen Park, ARC
	Julie Blackett, GRC
	Pat O'Neal, LaRC
Scheduler	Shirley Sternberg, AFRC
Risk Manager	Jamie Turner, AFRC
Change/Doc. Mgmt	Stacey Jenkins, AFRC
Admin	Lexie Gliwa, AFRC

Project Support: Technical

Staff Engineer	Dan Roth, AFRC
Systems Eng Lead	TBD, TBD

TECHNICAL CHALLENGE/ SUBPROJECT LEVEL

Detect and Avoid (DAA)
TC-DAA
Subproject Manager
Jay Shively, ARC
Subproject Technical Leads
Confesor Santiago, ARC; TBD, ARC;; Tod Lewis, LaRC

Command and Control (C2)
TC-C2
Subproject Manager
Mike Jarrell, GRC
Subproject Technical Lead
Jim Griner, GRC

Integrated Test & Evaluation
TC-ITE
Subproject Manager
Heather Maliska, AFRC
Subproject Technical Leads
Jim Murphy, ARC; Sam Kim, AFRC

ELEMNET/ TWP LEVEL

Technical Work Packages (TWP): Alternative Surveillance, Well Clear, ACAS Xu, External Collaboration, Integrated Events

Technical Work Packages (TWP): Terrestrial Extensions, Ku-/Ka-band SATCOM, C-band SATCOM

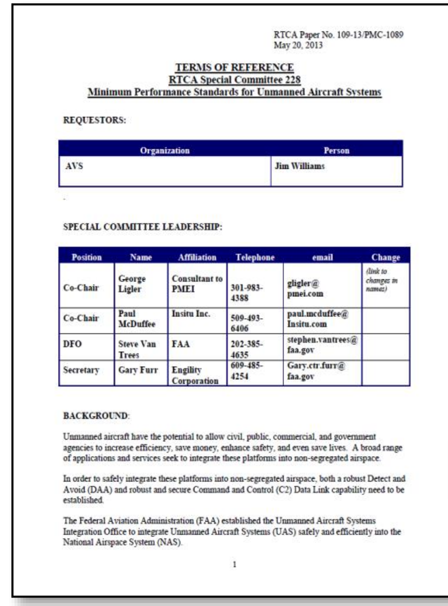
Technical Work Packages (TWP): LVIS Infrastructure Sustainment, Simulation Planning and Integration, Integrated Test Support

RTCA SC-228 Phase 1 MOPS Terms of Reference

RTCA SC-228 Terms of Reference (ToR) has defined a path forward to develop Minimum Operational Performance Standards (MOPS)

- Phase 1 MOPS are addressed by UAS-NAS Current (FY14 – FY16) Portfolio
  - Command and Control (C2) Data Link MOPS – Performance Standards for the C2 Data Link using L-Band Terrestrial and C-Band Terrestrial data links
  - Detect and Avoid (DAA) MOPS – Performance standards for transitioning of a UAS to and from Class A or special use airspace, traversing Class D and E, and perhaps Class G airspace

- SC-228 Deliverables
  - C2 & DAA White Papers (Dec 2013) - Assumptions, approach, and core requirements for UAS DAA and C2 Equipment
  - C2 & DAA MOPS for Verification and Validation (July 2015) – Preliminary MOPS Including recommendations for a Verification and Validation test program
  - C2 & DAA MOPS (July 2016) – Final MOPS



RTCA Paper No. 109-13/PMC-1089
May 20, 2013

TERMS OF REFERENCE
RTCA Special Committee 228
Minimum Performance Standards for Unmanned Aircraft Systems

REQUESTORS:

Organization	Person
AVS	Jim Williams

SPECIAL COMMITTEE LEADERSHIP:

Position	Name	Affiliation	Telephone	email	Change
Co-Chair	George Ligler	Consultant to PMEI	301-983-4388	gligler@pmei.com	*(link to changes in names)*
Co-Chair	Paul McDuffee	Insitu Inc.	509-493-6406	paul.mcduffee@Insitu.com	
DFO	Steve Van Trees	FAA	202-385-4635	stephen.vantrees@faa.gov	
Secretary	Gary Furr	Engility Corporation	609-485-4254	Gary.ctr.furr@faa.gov	

BACKGROUND:

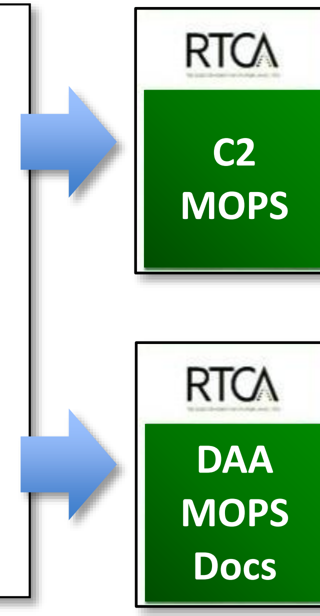
Unmanned aircraft have the potential to allow civil, public, commercial, and government agencies to increase efficiency, save money, enhance safety, and even save lives. A broad range of applications and services seek to integrate these platforms into non-segregated airspace.

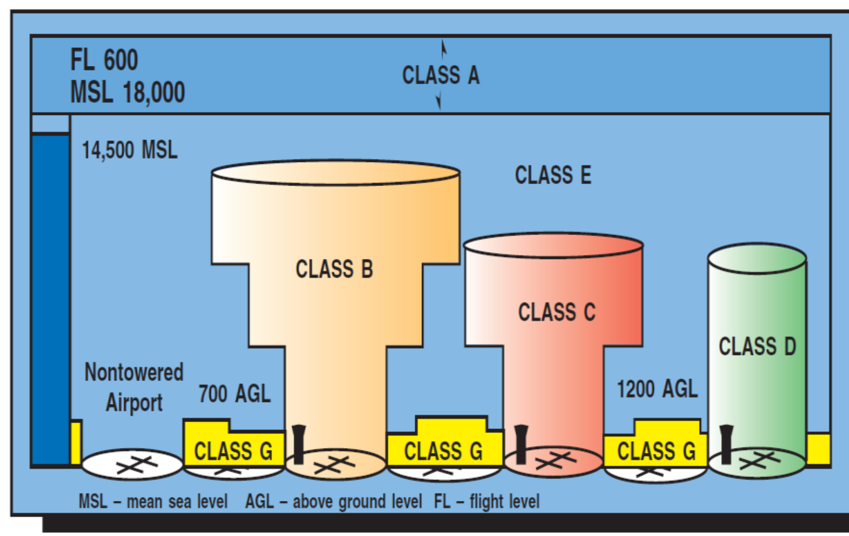
In order to safely integrate these platforms into non-segregated airspace, both a robust Detect and Avoid (DAA) and robust and secure Command and Control (C2) Data Link capability need to be established.

The Federal Aviation Administration (FAA) established the Unmanned Aircraft Systems Integration Office to integrate Unmanned Aircraft Systems (UAS) safely and efficiently into the National Airspace System (NAS).

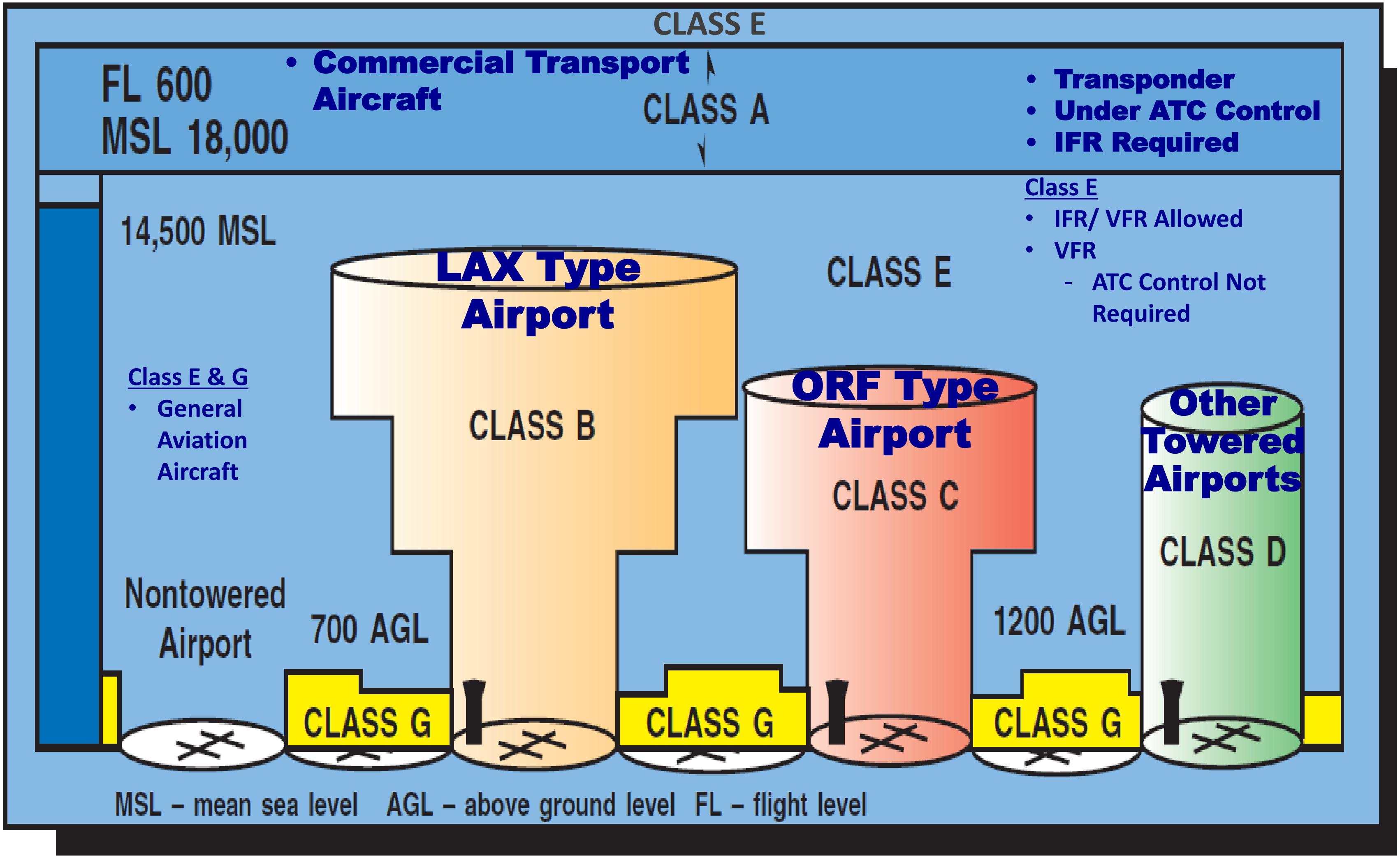
1

RTCA SC-228 ToR



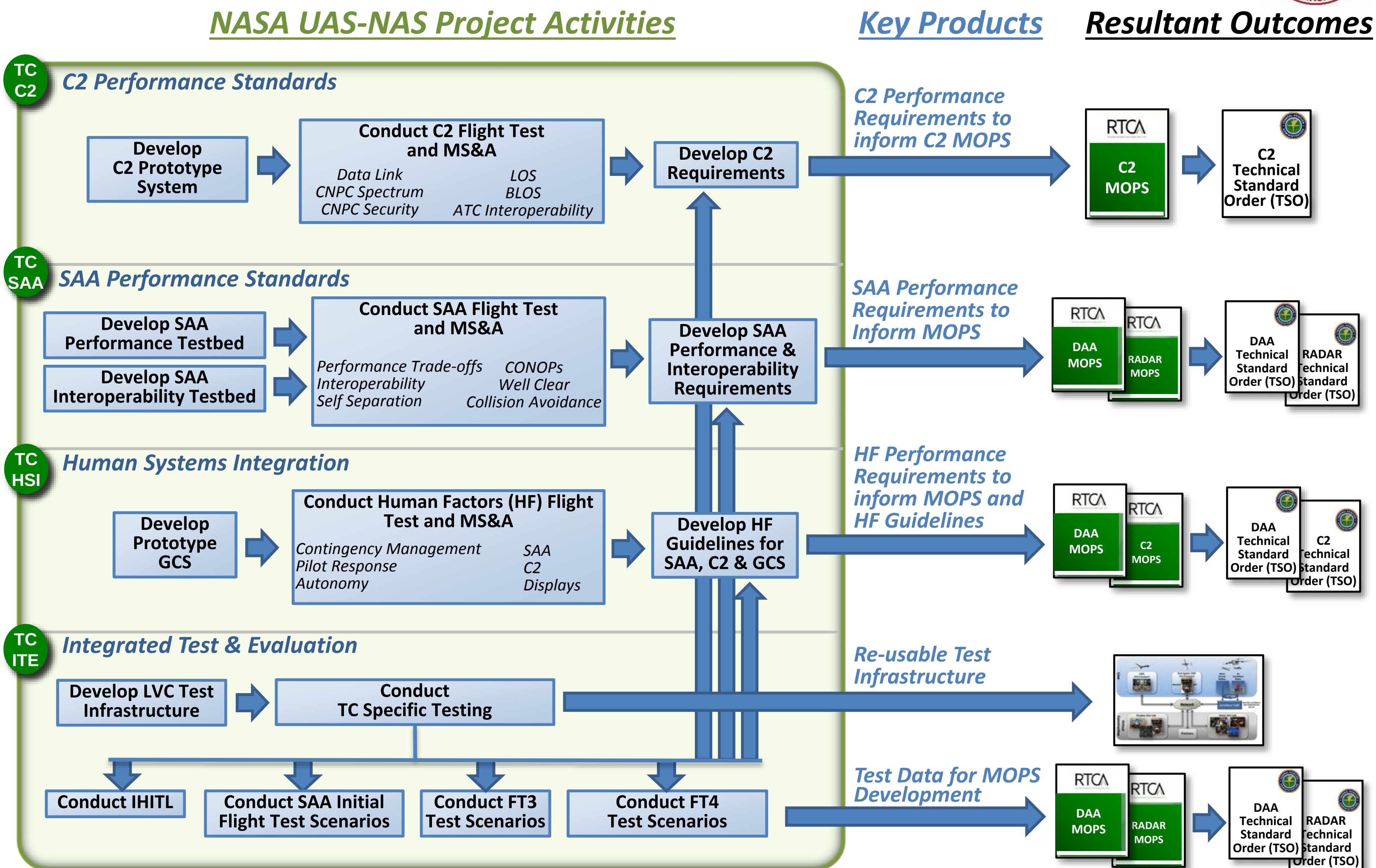


FAA Designated Airspace Classes



UAS Integration in the NAS Project

Phase 1 MOPS Value Proposition Flow Diagram



Technical Challenges & Partnership Plans Backup Slides

Fundamental TC Composition

- Data Removed

Technical Challenge Summary
UAS-NAS Phase 2 MOPS Technical Challenges

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C2 P2 MOPS Content Descriptions

- **C2 Data Link MASPS, SATCOM** (Oct 2017)
  - This MASPS will provide system performance requirements for SATCOM based C2. This material is specifically intended for delivery to ICAO to support their development of Standards and Recommended Practices (SARP) in preparation for World Radio Conference 2019.
- **C2 Data Link MOPS, SATCOM** (Jul 2019*)
  - This MOPS will provide system performance requirements for Ka/Ku technology based SATCOM based C2. This document is anticipated to lead to TSO for new functions of existing SATCOM terminals.
- **C2 Data Link MASPS, Network** (Jan 2019)
  - This MASPS will provide system level performance standards for multiple access network C2 applicable to both SATCOM and terrestrial based systems.
  - Provide multiple access techniques, augmenting the initial point-to-point architecture.
- **C2 Data Link MOPS, Terrestrial, Rev A** (Jul 2020)
  - This revision to the C2 Data Link MOPS (Terrestrial) will address: 1) any required updates resulting from ongoing TACAN/DME compatibility testing, 2) any required updates to harmonized shared use of C band between terrestrial and SATCOM systems, 3) any required updates to augment the original point-to-point MOPS description to include multiple access techniques and 4) any other updates to clarify or correct shortcomings identified while the document is open for changes.

- Other specific considerations for White Paper Development
  - C-Band SATCOM inclusion is time dependent
  - Architectures considered include: multiple aircraft communicating through a common ground or satellite transmitter, and single aircraft transitioning through a series of towers
  - Concept of operations and operating environment description for smaller UAS operating at lower altitudes

- **Date under discussion within RTCA SC-228 leadership and WGs**
- **Note: All content per August 2016 Draft SC-228 ToR**

C2 Overview

State of the Art:

- There are no civil SATCOM systems that meet initial RTCA C2 requirements established by SC-203
- RTCA SC-228 developed the Phase 1 MOPS which establishes C2 standards for a limited environment
  - Terrestrial C2 architecture only
  - Higher altitude coverage expected for "larger" UAS operations
  - Lower-density operations than expected for "mid-sized" UAS

Related NASA Work:

- Performed/supported spectrum studies used for establishing Ku & Ka-Band designations and C-Band SATCOM allocation at WRC-12 & 15
- Developed multiple generations of a CNPC terrestrial radio evaluation system through a NASA/Industry cooperative agreement
- Leadership of the RTCA SC-228 C2 (WG Security and V&V subgroups) and significant contributions to the Phase 1 Terrestrial C2 MOPS
- NASA developed NAS-wide communications simulation model

Remaining Challenge/Barrier/Gap:

- An appropriate C2 link that supports the required performance needs of a broad range of UAS platforms
  - Ensures the pilot can maintain a threshold level of aircraft control
  - Robust to both environmental and technological issues
- Sufficient bandwidth efficiency to meet the anticipated UAS density levels
- Maturation of C2 terrestrial and SATCOM technologies

NASA's Unique Positioning:

- Terrestrial and SATCOM C2 Subject Matter Expertise and familiarity with the key issues
- Recognized leader of ongoing efforts and working groups (e.g. WRC, ITU, SC-228)
- Instills confidence in industry that standards will be accepted by the regulator
- Able to leverage previous hardware and software investments as well as M&S and flight test assets used for Phase 1 MOPS

C2 Overview

Objectives:

- Develop data and rationale to acquire UAS frequency spectrum allocations for SATCOM
- Develop and validate UAS control and communications data links for MOPS in compliance with proposed international/national regulations, standards, and practices
- Perform analysis and propose security recommendations for civil UAS control communications
- Perform simulations studying link scalability, capacity testing, and interoperability testing

Key Activities:

- Develop Ku & Ka SATCOM prototype radio systems through a NASA/Industry cost sharing cooperative agreement
- Develop the Initial design parameters for a C-band SATCOM CNPC system
- Develop a C & L-Band terrestrial extension CNPC prototype radio systems through a NASA/Industry cost sharing cooperative agreement
- All prototype systems will be flight tested in a relevant environment

TC Advancement:

- Valuable research findings to SC-228 for Phase 2 C2 MOPS development
- Substantiated UAS frequency spectrum allocations for SATCOM
- Proven terrestrial C & L-band architecture applicable to a broader set of UAS
- Validated Terrestrial Extension and SATCOM C2 Standards

DAA P2 MOPS Content Descriptions

- **Ground-based Primary Radar MOPS and DAA MOPS Rev A** (Sep 2019)
  - MOPS for a ground-based primary radar to support the Phase 2 DAA MOPS
  - Geographically limited operations and operations within a terminal environment should be considered to include; Class D airspace, towered airfields within Class E airspace, non-towered airfields within Class E airspace, non-towered airfields within Class G airspace, and off-airfield launch and recovery sites within Class G airspace
- **Non-Cooperative Sensor MOPS and DAA MOPS Rev B** (Sep 2020)
  - MOPS for an alternative sensor to detect and track non-cooperative aircraft in support of the Phase 2 DAA MOPS
  - Technologies to enable UAS with less available Size, Weight, and Power (SWaP) should be considered. It is expected that this will lead to the development of a MOPS for a non-cooperative sensor

- Other specific considerations for White Paper Development
  - A collision avoidance capability that operates in the absence of a C2 Datalink
  - Elaborate potential Visual Operations that could be enabled with a Phase II DAA Capability
  - Operations in other classes of airspace (e.g. Classes B and C)
  - Very Low Level (VLL) operations, which includes extended operations below 500 ft AGL, are not within the scope of Phase Two DAA MOPS
  - Ground operations by UAS are not in scope of Phase Two DAA MOPS

- **Note: All content per August 2016 Draft SC-228 ToR**

DAA Overview

State of the Art:

- A significant amount of DAA research has been conducted by the UAS community over the past several years. Centered on:
  - Government research efforts
  - Industry IRAD funded prototype systems
- RTCA SC-228 developed the Phase 1 MOPS which establishes DAA standards for a limited environment
  - Transition through Class E to Class A
  - Onboard radars as non-cooperative sensors

Related NASA Work:

- The NASA UAS-NAS DAA subproject played a key role in the development of the Phase 1 MOPS
- Worked in close coordination with the Science and Research Panel (SARP) to develop the Well Clear Definition
- Developed and evaluated two DAA algorithms using M&S and flight test
- Developed alerts and guidance consistent with existing collision avoidance systems (e.g., TCAS)

Remaining Challenge/Barrier/Gap:

- DAA Standards, CONOPs and Use Cases for UAS operations within all remaining classes of airspace (B, C, D, E, G)
- DAA technologies and standards for use on a broad range of UAS platforms
- DAA Standards for low-SWaP alternative sensors and GBSAA
- DAA technologies and avoidance algorithm maturation to more broadly applicable environments

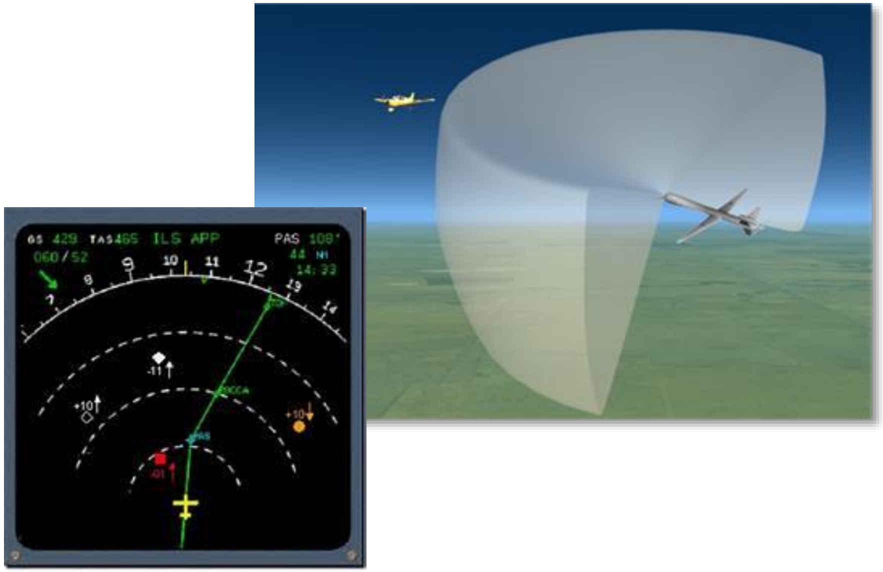
NASA's Unique Positioning:

- Broad DAA Subject Matter Expertise and capabilities; Familiarity with the issues of a difficult problem for the community to solve
  - Able to leverage previous investments such as algorithms, simulation environments, and flight test assets
- Instills confidence in industry that standards will be accepted by the regulator
- Recognized leader in ongoing efforts and working groups (e.g. FAA, SARP, SC-228)

DAA Overview

Objectives:

- Evaluation and Integration alternative airborne sensors
- Support SC-228 and Enable UAS Terminal **and/or** BVLOS ops for UAS with lower available SWaP (including well clear definitions)
- Rules/logic for ACAS Xu interoperability
- Procedures for safe and efficient UAS Operations
- Evaluate requirements and implications of autonomous DAA with MOPS



Key Activities:

- Conduct engineering analysis
- Perform fast time simulations
- Perform Human in the Loop (HITL) simulations
- Perform flight tests to V&V DAA requirements and Standards

TC Advancement:

- Valuable research findings to SC-228 for Phase 2 MOPS development
- FAA policy/guidance finalization for DAA
- Broadly applicable well clear definition(s) and ATM interoperability
- Safe and efficient unsegregated terminal area operations for UAS
- Low SWaP DAA system definition, testing and validation

IT&E Overview

State of the Art:

- LVC-DE environment built for phase 1 MOPS
- NASA Ikhana equipped with prototype DAA system and used in multiple flight tests
- Phase 1 C2 prototype system flight tested and available through GRC
- Data from LVC-DE & flight tests used to help V&V Phase 1 MOPs
- Army GBSAA radar based on dedicated ground observer architecture
- Industry low-SWaP airborne sensors, and ground sensors developed with significant industry IRAD being invested

Related NASA Work:

- The NASA UAS-NAS IT&E subproject played a key role in validating the Phase 1 MOPS through M&S and flight test
  - Phase 1 MOPS Verification Procedures defined
  - Phase 1 MOPS Validation Flight Tests
- Executed integration and flight tests for P1 DAA MOPS
  - ~320 DAA V&V encounters performed

Remaining Challenge/Barrier/Gap:

- Existing Phase 1 MOPS are not intended for operations within terminal areas or for UAS with lower available SWaP
- GBSAA and Low-SWaP airborne sensors have not been integrated into DAA or C2 architectures
- DAA performance specs not yet developed or validated for use on a broad range of UAS platforms
- Automatic Collision Avoidance systems for UAS do not have standards
- Integration of DAA and C2 on board UAS has not been complete, and methods operational approvals of systems have not been developed

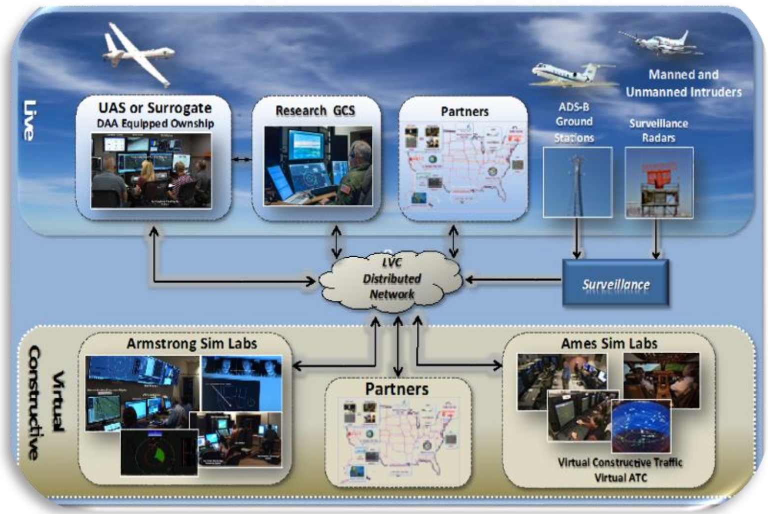
NASA's Unique Positioning:

- Flight Test required for V&V and performance standards is challenging and high risk
  - Able to leverage previous investments such as, LVC-DE, flight test assets, FT3 & FT4 risk reduction & DAA flight test operation experience.
- Instills confidence in industry that standards will be accepted by the regulator
- Recognized leader in ongoing efforts and working groups (e.g. FAA, SARP, SC-228)

IT&E Overview

Objectives:

- Design, document, develop, implement, operate, and maintain a LVC-DE for simulation and flight test
- Simulation planning, conduct, data distribution, and reporting
- Plan, conduct, distribute data, and report on flight tests, including; Collision Avoidance flight tests, DAA focused flight tests, and integrated DAA and C2 flight tests



Key Activities:

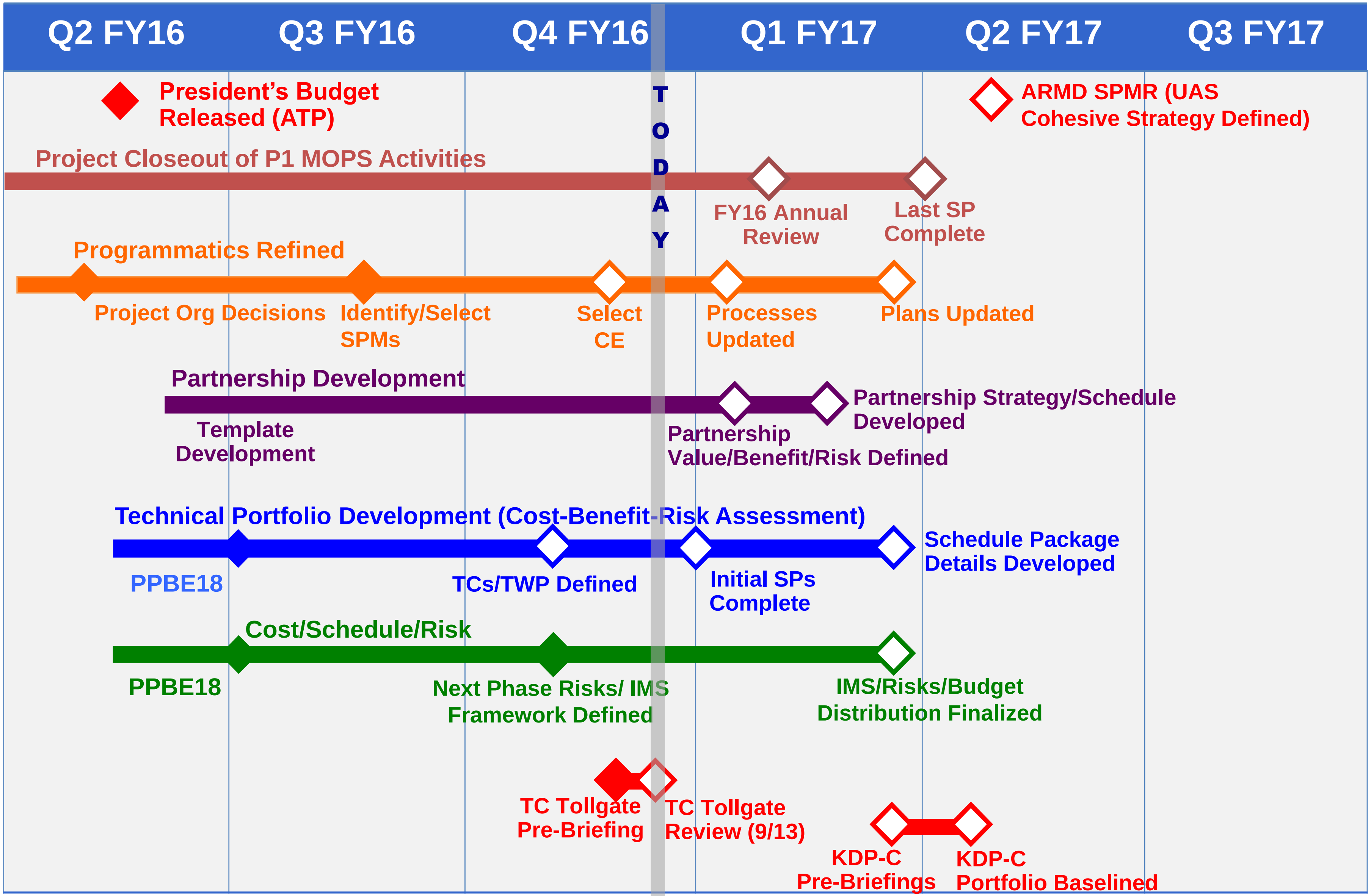
- Employing system engineering principles define:
  - LVC-DE infrastructure design requirements
  - Simulation experiment requirements
  - Flight test requirements
  - Data and data distribution requirements
- Develop and document partnerships
- Support multiple DAA simulations
- Collaborate with ACAS Xu partners to plan and conduct ACAS Xu FT2
- Conduct a series of flight tests in support of MOPS development, verification and validation

TC Advancement:

- Simulation/flight systems and infrastructure for development, verification and validation of MOPS
- Rigorous NASA safety processes applied against SOA aircraft and technology systems in order to conduct highly complex testing

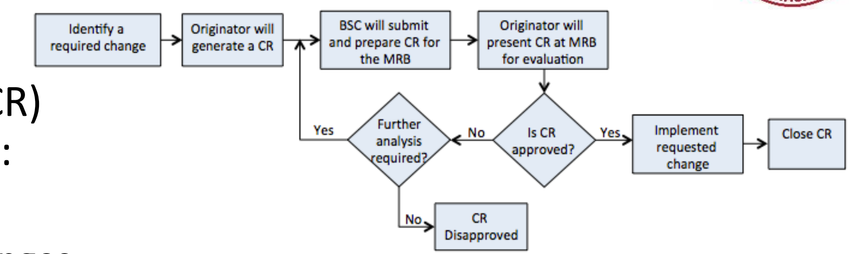
Path to KDP-C Backup Slides

Overview Schedule to KDP-C



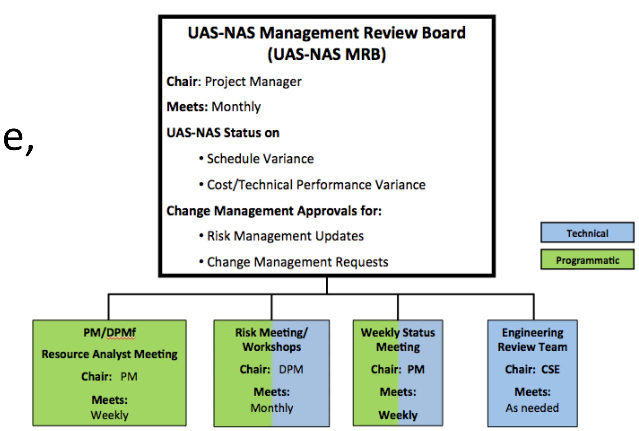
Project Processes

- Change Management
  - Standard process utilizing Change Requests (CR) to manage changes to the following elements:
    - L1 and L2 Milestones
    - Project Goals, Objectives, and Technical Challenges
    - Technical Baseline, i.e. SP objective, approach, deliverables
    - Project Requirements
    - Budget



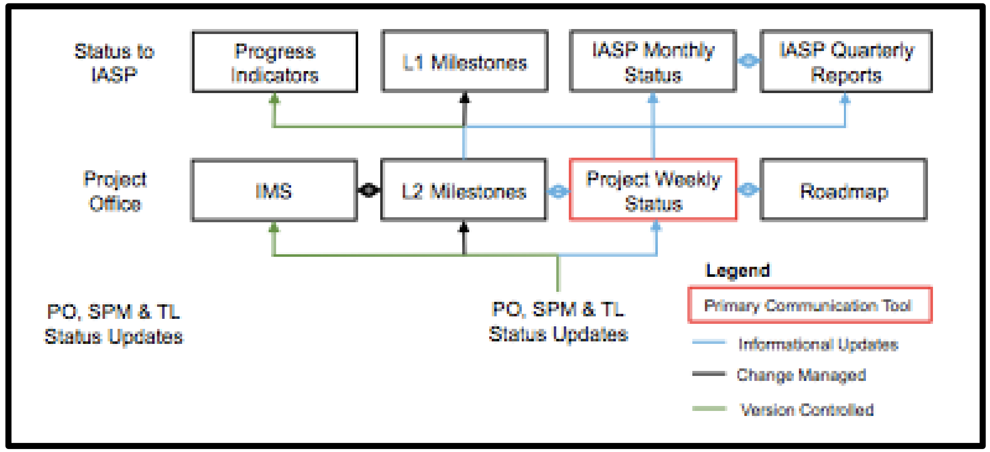
- Risk Management
  - Utilizes a Continuous Risk Management (CRM) process to identify, analyze, plan, track, and control risks
    - Risk Workshops and Risk Review meetings conducted monthly
    - Risks are communicated in ISRP UAS-NAS Risk Review Board, AFRC & Partner Center CMCs

- Resource Management
  - TWP, Budget roll up, and travel spreadsheets used in conjunction with standard tools (PMT, Business Warehouse, and SAP) to generate phasing plans and monitor status
- Management Review Board (MRB)
  - Monthly meeting where CRs and Risks are assessed/ approved and resource status and schedule status are presented



Project Processes
Schedule Management Flow

- Project weekly status is the primary means of information flow, schedule status, and updates
- Schedule Packages and Milestones are the primary means of reporting at the project weekly status
- The version controlled IMS contains change managed Milestones



Representative TC Task	M/S Level	Begin Date	End Date	Status/Progress /Concerns
Schedule Package N				Technical, Schedule, Accomplishments, and Issues and Concerns Status
Active Task1		01/01/14	02/15/14	complete
Active Task2		01/20/14	02/28/14	ongoing
Active Task3		02/01/14	03/31/14	ongoing
Deliverable	D	03/15/14	03/15/14	
Milestone	L2	04/01/14	04/01/14	

- Schedule management process is formally documented in the SMP

Acronyms

ACAS	Airborne Collision Avoidance System
ACAS Xu	Airborne Collision Avoidance System for Unmanned Aircraft Systems
ACES	Airspace Concept Evaluation System
ACSS	Aviation Communication & Surveillance Systems
ADS-B	Automatic Dependent Surveillance - Broadcast
AFLCMC	Air Force Life Cycle Management Center
AFRC	Armstrong Flight Research Center
AFRL	Air Force Research Lab
AGL	Above Ground Level
AI	Airspace Integration
AMS(R)S	Aeronautical Mobile-Satellite (R) Service
ARC	Ames Research Center
ARD	Aeronautics Research Director
ARMD	Aeronautics Research Mission Directorate
ATC	Air Traffic Controller
ATM	Air Traffic Management
ATO	Air Traffic Organization-FAA Organization or Authority to Operate
BLOS	Beyond Line of Sight
AUVSI	Association for Unmanned Vehicle Systems International
BRLOS	Beyond Radio Line of Sight
BVLOS	Beyond Visual Line of Sight

Acronyms

C2	Command and Control or Control and Communications
CA	Collision Avoidance
CDR	Critical Design Review
CMC	Center Management Council
CE	Chief Engineer
CNPC	Control and Non-Payload Communications
COA	Certificate of Authorization or Waiver
CONOPS	Concept of Operations
CPDS	Conflict Prediction and Display System
CR	Change Request or Continuing Resolution
CRM	Continuous Risk Management
CST	Combined Systems Test
DAA	Detect and Avoid
DME	Distance Measuring Equipment
DPMC	Directorate Program Management Council
EO	Electro Optical
EUROCAE	European Organization for Civil Aviation Equipment
F2F	Face to Face
FAA	Federal Aviation Administration
FT	Flight Test
FY	Fiscal Year

Acronyms

GA	General Aviation or General Atomics
GA-ASI	General Atomics Aeronautical Systems Inc.
GBSAA	Ground Based Sense and Avoid
GCS	Ground Control Station
GCSI	Ground Control Station for Integration
GRC	Glenn Research Center
HALE	High Altitude Long Endurance
HF	Human Factors
HITL	Human in the loop
HW	Hardware
HSI	Human Systems Integration
IASP	Integrated Aviation Systems Program
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IFR	Instrument Flight Rules
IFT	Integrated Flight Test
IHITL	Integrated Human in the loop
IMS	Integrated Master Schedule
IRAD	Internal Research and Development Program
IT&E	Integrated Test and Evaluation
ITU	International Telecommunication Union

Acronyms

ITU-R	International Telecommunication Union-Radiocommunication
JADEM	Java Architecture for Detect and Avoid Extensibility and Modeling
JOFOC	Justification of Other than Full and Open Competition
KDP	Key Decision Point
L1	Level 1
L2	Level 2
LaRC	Langley Research Center
LIDAR	Light Imaging, Detection, And Ranging
LAX	Los Angeles International Airport
LOS	Line of Sight or Loss of Separation
LVC	Live Virtual Constructive
LVC-DE	Live Virtual Constructive- Distributed Environment
LVIS	Live Virtual Integrated System
M&S	Modeling & Simulation
MS&A	Modeling, Simulation and Analysis
MASPS	Minimum Aviation System Performance Standards
MIT-LL	Massachusetts Institute of Technology Lincoln Labs
MOA	Memorandum of Agreement
MOPS	Minimum Operational Performance Standards
MOU	Memorandum of Understanding
MRB	Management Review Board

Acronyms

NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NextGen	Next Generation
NGC	Northrop Grumman Corporation
NSPIRES	NASA Solicitation and Proposal Integrated Review and Evaluation System
OE	Operational Environment
Ops	Operations
ORF	Norfolk International Airport
P1	Phase 1
P2	Phase 2
PAA	Program Analysis and Alignment
PDR	Preliminary Design Review
PM	Program Manager
PMT	Project Management Tool
PPBE	Planning, Programming, Budgeting, and Execution
RFI	Request for Information
RFP	Request for Proposal
SAA	Space Act Agreement or Sense and Avoid or See and Avoid
SAP	Systems Applications and Products
SARP	Science and Research Panel
SATCOM	Satellite Communication

Acronyms

SC	Special Committee
SMP	Schedule Management Plan
SOA	State of Art
SOW	Statement of Work
SP	Schedule Package
SPM	Subproject Manager
SPMR	Strategic Portfolio Management Review
SW	Software
SWaP	Size, Weight and Power
TACAN	Tactical Air Navigation System
TBD	To Be Determined
TC	Test Conductor/Technical Challenge
TCAS	Traffic Alert and Collision Avoidance System
TL	Technical Lead
ToR	Terms of Reference
TSO	Technical Standard Order
TWP	Technical Work Package
UAS	Unmanned Aircraft Systems
UAS-NAS	UAS Integration in the NAS
USAF	United States Air Force
V&V	Verification and Validation

Acronyms

VLL	Very Low Level
WG	Working Group
WRC	World Radio Conference