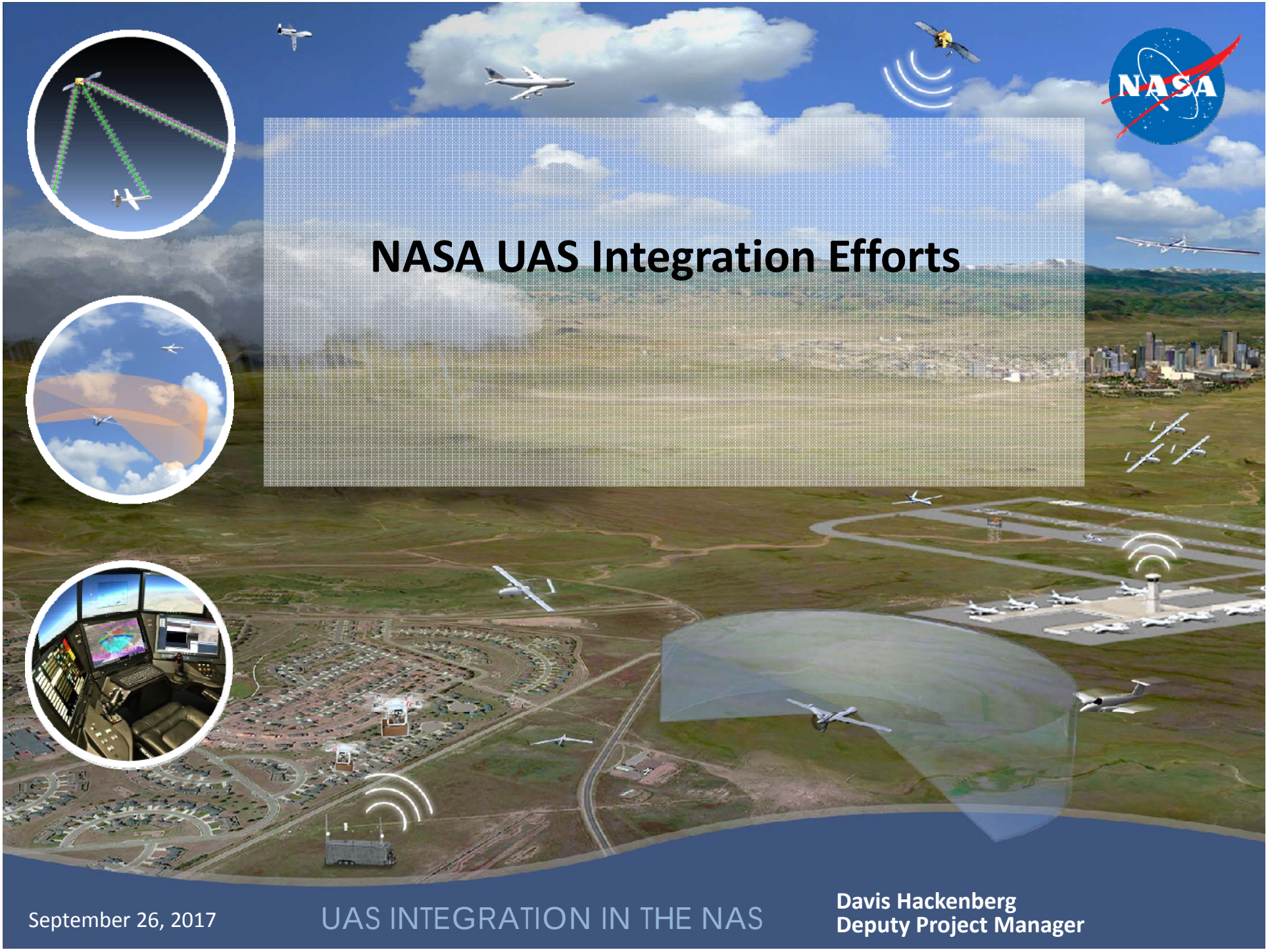
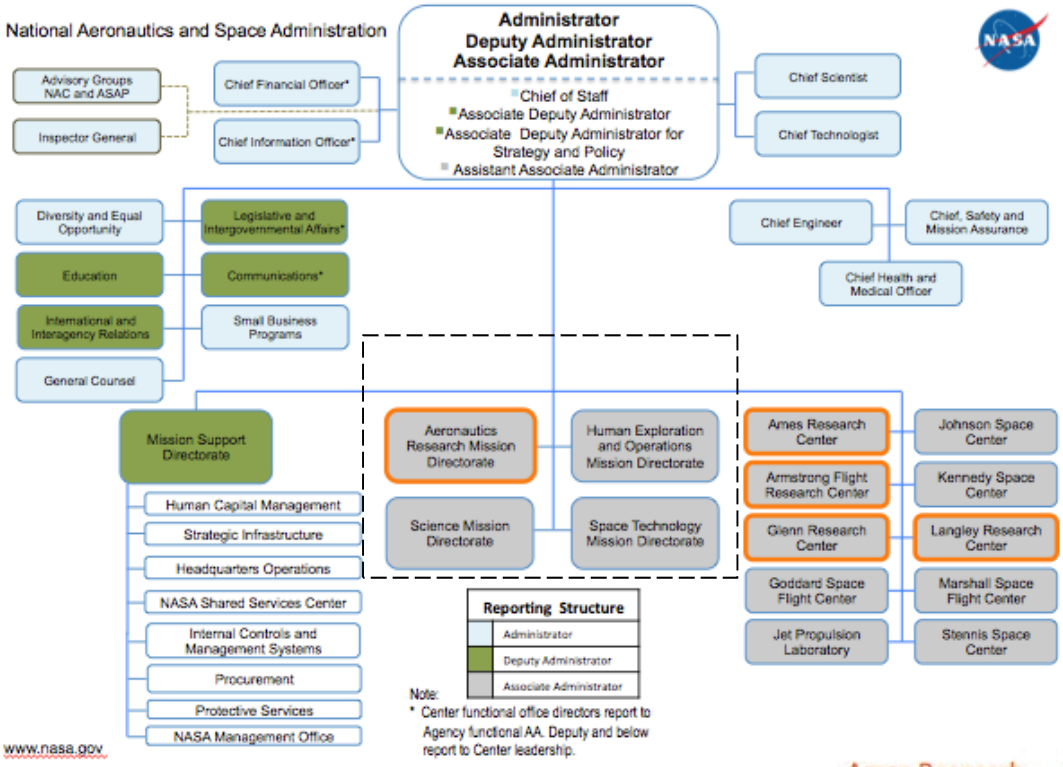

NASA UAS Integration Efforts
September 26, 2017
UAS INTEGRATION IN THE NAS
Davis Hackenberg
Deputy Project Manager

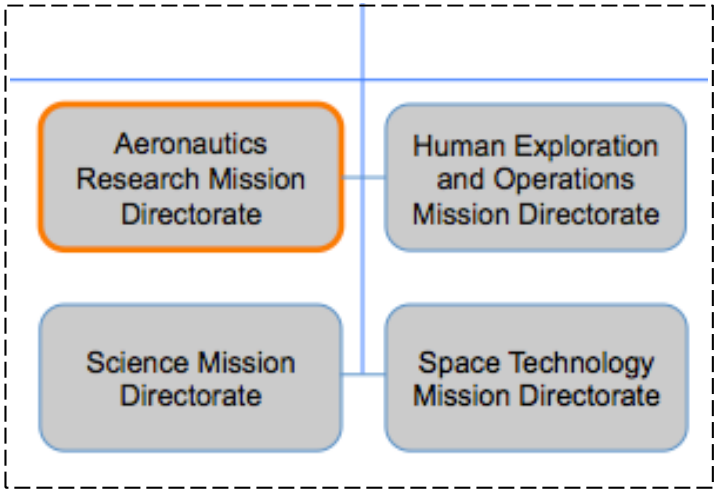
Discussion Topics

- NASA Organization
- NASA UAS Integration Strategy
- UAS Integration in the NAS Project Overview

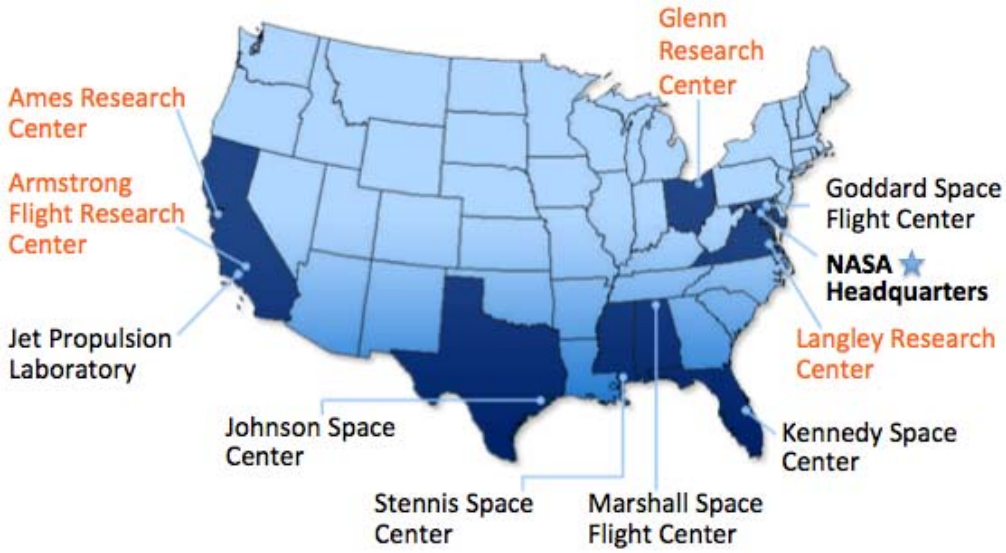
NASA Organizational Structure



Mission Directorates



Aeronautics Research Centers



ARMD Organizational Structure, Programs Overview

MISSION PROGRAMS

Airspace Operations and Safety Program

AOSP

- **Safe, Efficient Growth in Global Operations**
- **Real-Time System-Wide Safety Assurance**
- **Assured Autonomy for Aviation Transformation**

Advanced Air Vehicles Program

AAVP

- **Ultra-Efficient Commercial Vehicles**
- **Innovation in Commercial Supersonic Aircraft**
- **Transition to Low-Carbon Propulsion**
- **Assured Autonomy for Aviation Transformation**

Integrated Aviation Systems Program

IASP

- **Flight research-oriented, integrated, system-level R&T that supports all six thrusts**
- **X-planes/ test environment**

SEEDLING PROGRAM

Transformative Aeronautics Concepts Program

TACP

- **High-risk, leap-frog ideas that support all six thrusts**
- **Critical cross-cutting tool development**

NASA ARMD
Cohesive UAS Integration Strategy

September 26, 2017

UAS INTEGRATION IN THE NAS

Davis Hackenberg
Deputy Project Manager

Scope / Outcome

Scope: Focus on what is needed to enable full integration of UAS for civil / commercial operations within the NAS by ~2025

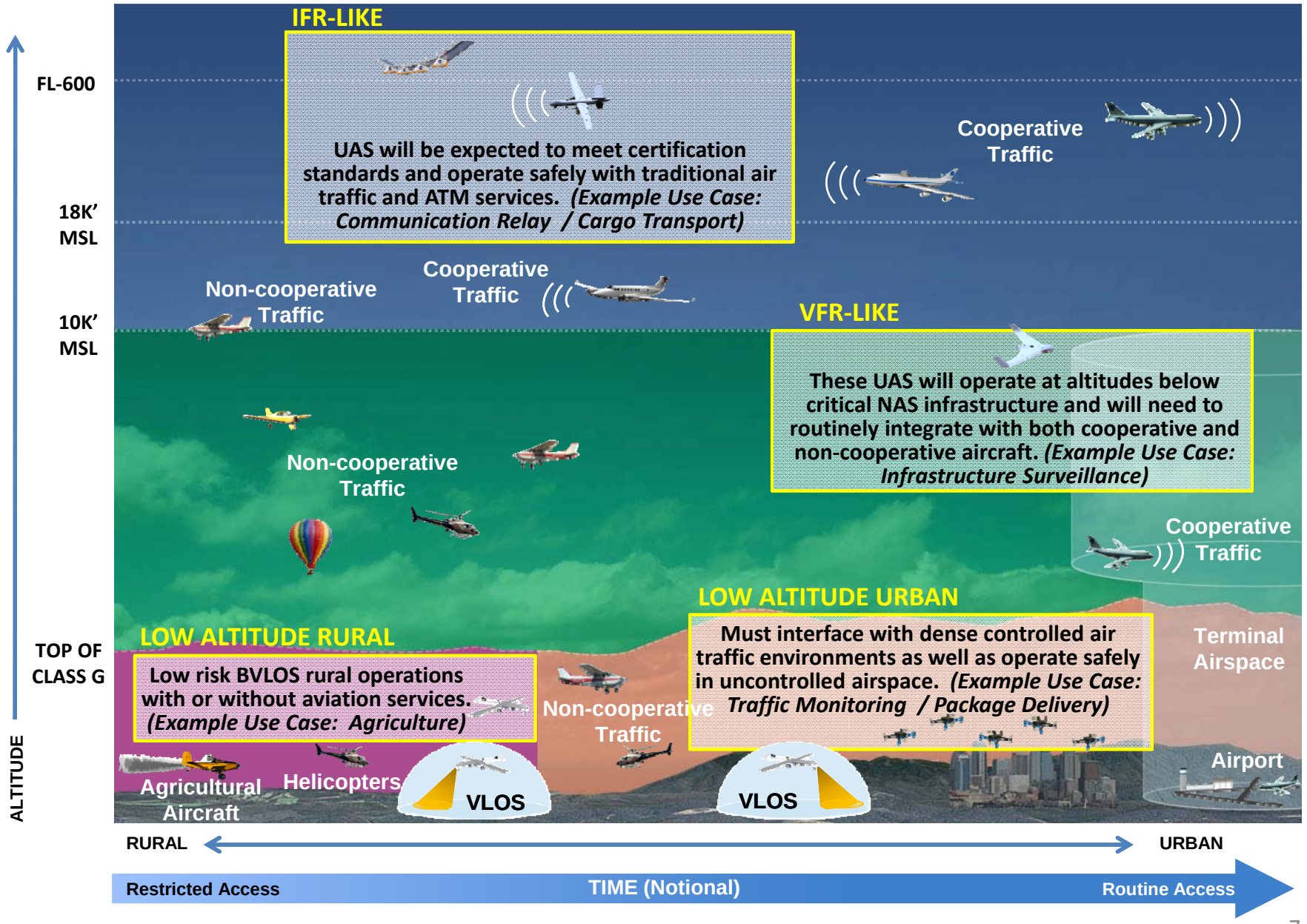
- Top level strategy that assesses stakeholder needs, FAA UAS Integration Strategy, Concept of Operations, Implementation Plans, etc.
- Leverage information from Government-wide R&D Analysis (ExCom) and FAA R&D Roadmap

Outcome: A Vision, Strategic Plan and Communication Strategy

- Routine UAS access within the NAS
- Concept for transitioning UAS access advancements towards the integration of highly autonomous systems and on-demand mobility

Enabling Full Integration of UAS for civil / commercial operations within the NAS by ~2025

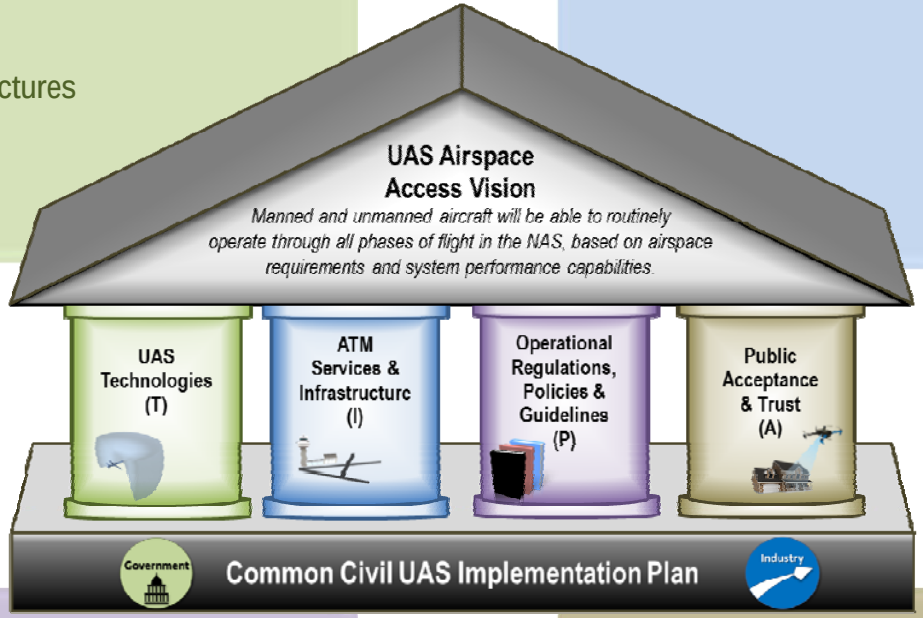
Future Civil UAS Airspace Environment



UAS Airspace Access Enablers

UAS Technologies:
T01 - Airport Operations Technologies
T02 - Airworthiness Standards
T03 – Command, Control, Communications (C3)
T04 - Detect & Avoid (DAA)
T05 - Flight & Health Mngmt Systems
T06 - GCS Technologies
T07 - Hazard Avoidance
T08 - Highly Automated Architectures
T09 – Navigation
T10 - Power & Propulsion
T11 - Weather

ATM Services & Infrastructure:
I01 - Airport Infrastructure
I02 - ATM Infrastructure
I03 - Non-FAA Managed Airspace Infrastructure
I04 - RF Spectrum Availability
I05 - Test Ranges & M&S Facilities



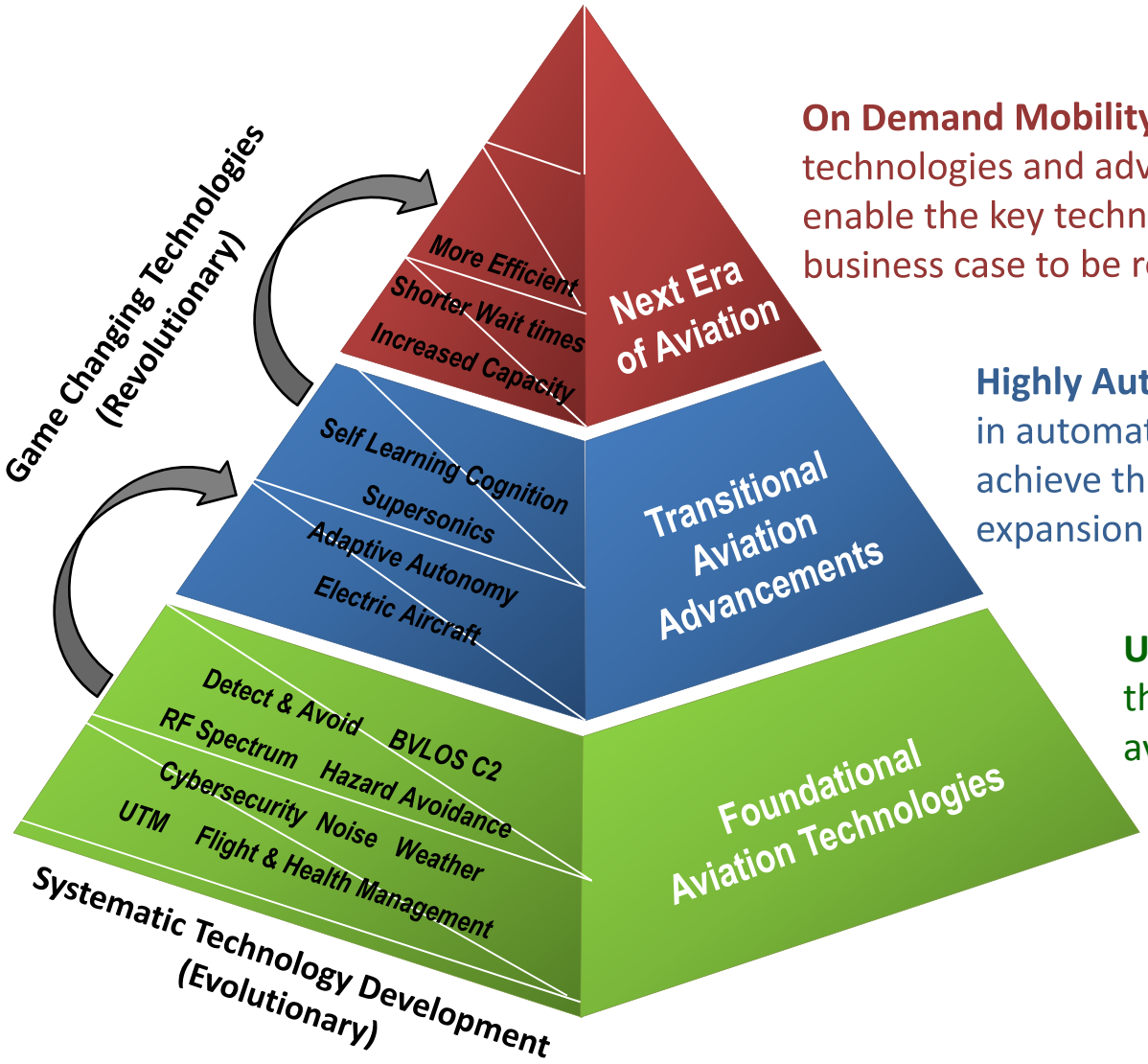
Operational Regulations, Policies & Guidelines:
P01 - ATM Regulations / Policies / Procedures
P02 - Airworthiness Regulations / Policies / Guidelines
P03 - Operating Rules / Regulations / Procedures
P04 - Safety Risk Mngmt & Methods of Compliance

Public Acceptance & Trust:
A01 - Cybersecurity Criteria & Methods of Compliance
A02 - Legal & Privacy Rules / Guidelines
A03 – Noise Reductions
A04 - Physical Security Criteria & Methods of Compliance
A05 - Public Safety Confidence

Overarching UAS Community Strategy

- The future civil UAS airspace environment is a complex picture with many unique considerations across the various operating environments
  - Operating environment attributes and community needs must be considered in order to provide routine access for a diverse set of UAS demand scenarios
- UAS airspace access pillars are a simple decomposition method to structure the broad needs of this diverse community
  - UAS Airspace Access Enablers provide another layer of detail to consider research elements necessary to achieve the routine access vision
- Assessing the intersections of the future civil UAS airspace environments and UAS airspace access pillars was the method chosen to develop the overarching UAS Community Strategy
  - Operating Environment Roadmaps were developed around these intersections and the community needs necessary to enable routine UAS access
  - **Assessments were performed against "routine UAS access," rather than an autonomous end state**

Achieving the Next Era of Aviation



On Demand Mobility - ODM will leverage UAS technologies and advancements in automation to enable the key technologies needed for the ODM business case to be realized

Highly Autonomous Systems – advancements in automation will open the door for UAS to achieve their full potential and market expansion

UAS Integration - UAS Integration is the foundation for the revolution of the aviation industry

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

Davis Hackenberg
Deputy Project Manager

UAS-NAS Phase 2 (other acting) Project Organization Structure

PROJECT OFFICE LEVEL

Project Leadership

Project Manager (PM)	Robert Sakahara, AFRC (A)
Deputy PM	Davis Hackenberg, AFRC (A)
Chief Engineer (CE)	William Johnson, LaRC

Project Support

Sr. Advisor	Chuck Johnsons, AFRC
Staff Engineer	Dan Roth, AFRC
Lead Resource Analyst	April Jungers, AFRC
Resource Analysts	Amber Gregory, AFRC
	Warcquel Frieson, ARC
	Julie Blackett, GRC
	Pat O'Neal, LaRC
Scheduler	Irma Ruiz, AFRC
Risk Manager/Outreach	Jamie Turner, AFRC
Change/Doc. Mgmt	Lexie Brown, AFRC
Admin Support	Sarah Strahan, AFRC

Project Systems Engineering Office

Deputy Chief Engineer	TBD, AFRC
SIO Technical Manager	TBD, LaRC
Test and Evaluation Lead for SIO	TBD, AFRC
DAA Technical Integration Lead for SIO	TBD, ARC
C2 Technical Integration Lead for SIO	TBD, GRC

SUBPROJECT LEVEL

Command and Control (C2)

Subproject Manager

Mike Jarrell, GRC

Subproject Technical Lead

Jim Griner, GRC

Detect and Avoid (DAA)

Subproject Manager

Jay Shively, ARC

Subproject Technical Lead

Gilbert Wu (A)/Confesor Santiago, ARC; Lisa Fern; ARC; Tod Lewis, LaRC

Integrated Test and Evaluation (IT&E)

Subproject Manager

Mauricio Rivas, AFRC (A) /Jim Murphy, ARC (A)

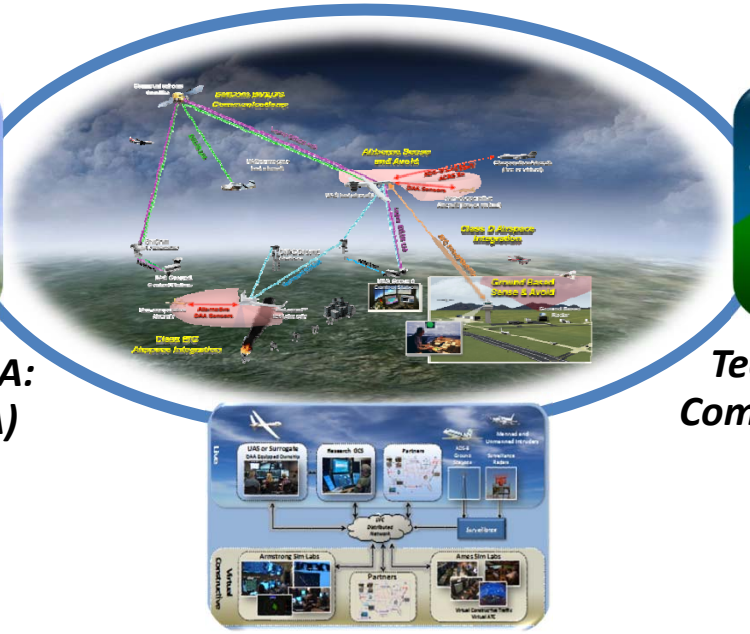
Subproject Technical Lead

Ty Hoang, ARC (A) ; Sam Kim, AFRC

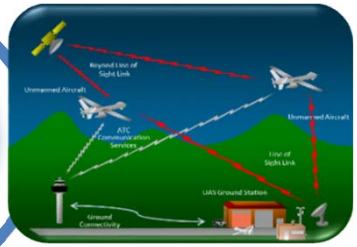
Notional

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

Technical Challenge-DAA: Detect and Avoid (DAA)



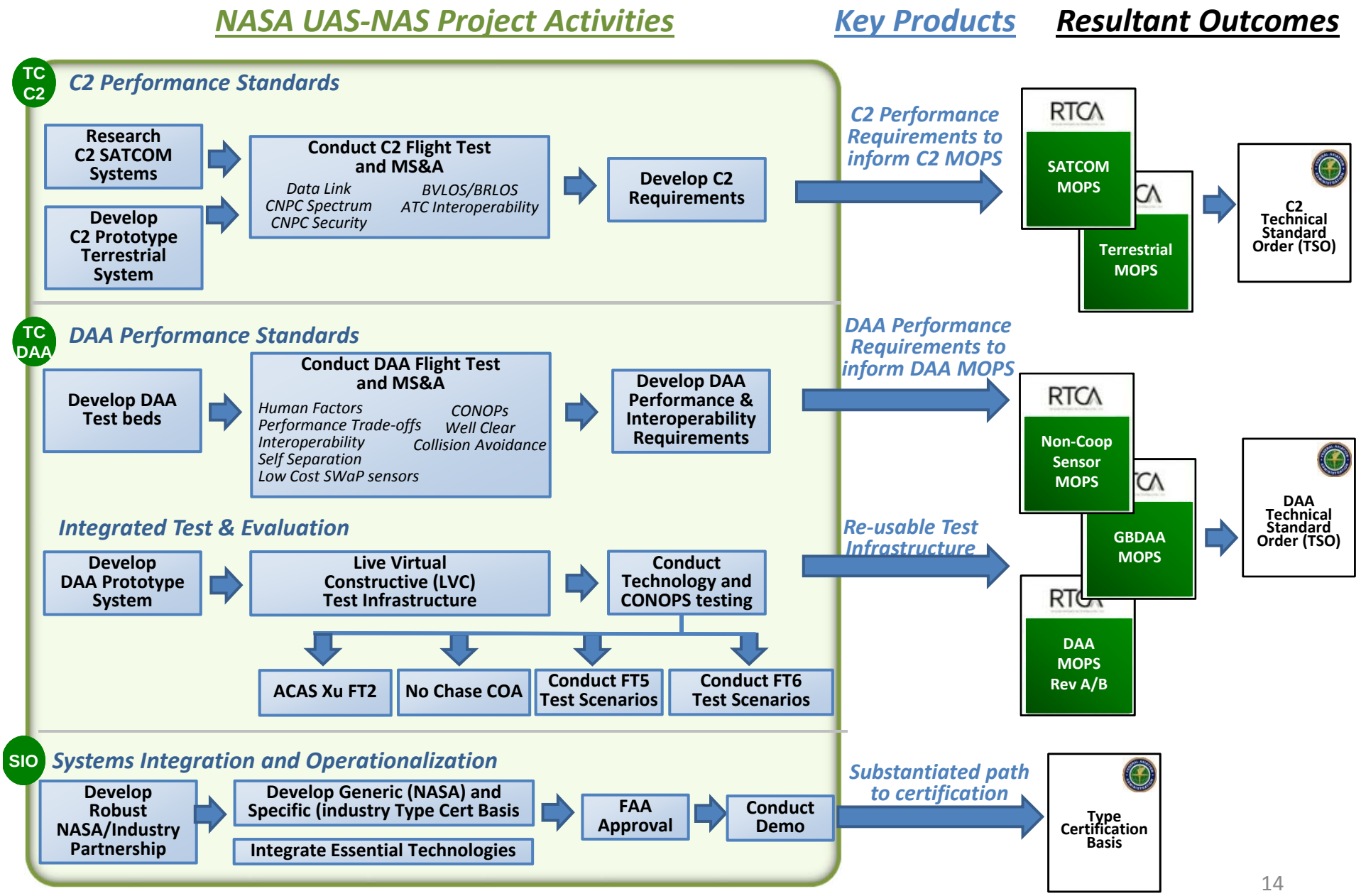
Systems Integration and Operationalization (SIO)



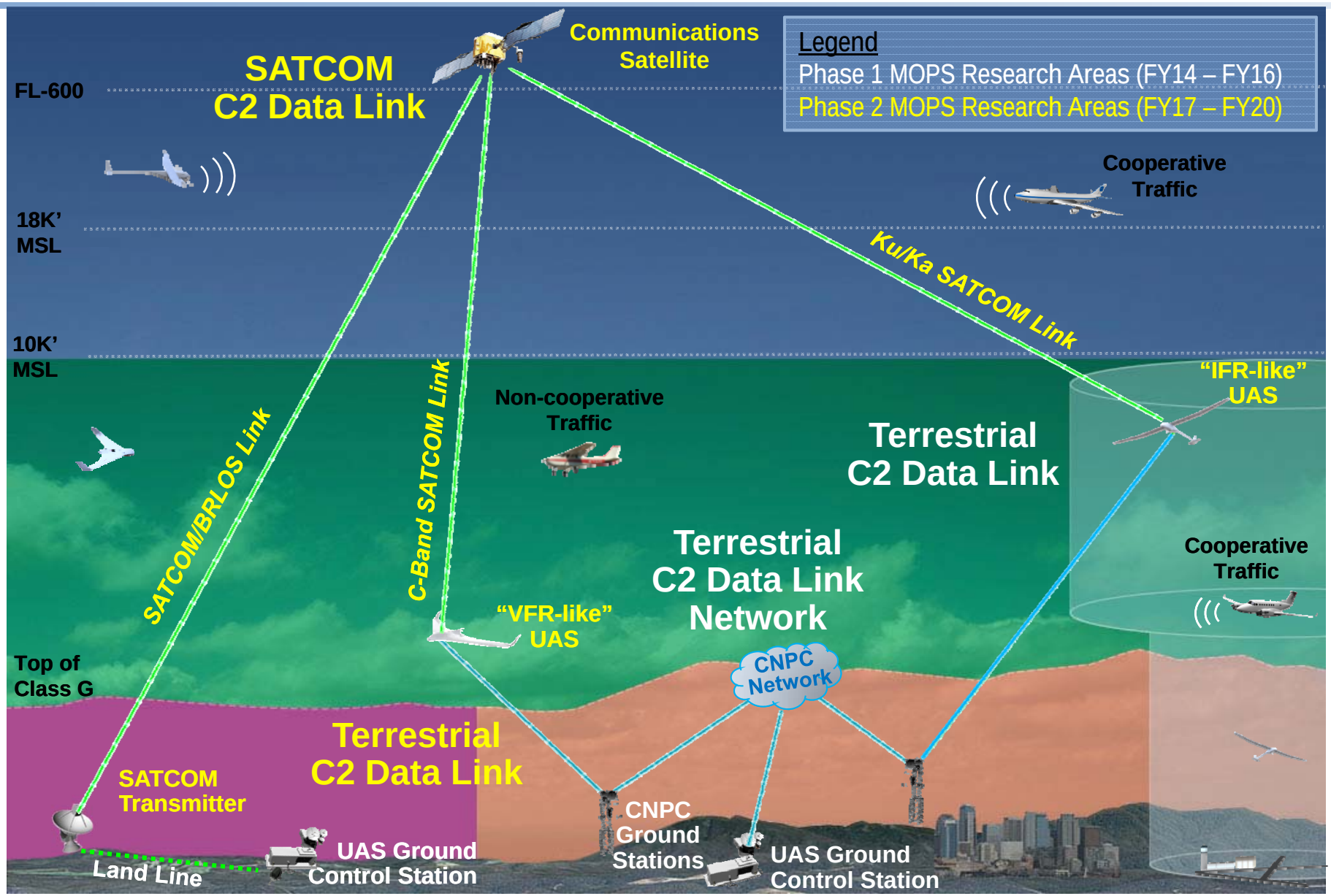
Technical Challenge-C2: Command and Control (C2)

update

UAS-NAS Project Value Proposition



UAS-NAS Command and Control (C2) Operating Environments (OE)



C2 Subproject Structure for Project Phase 2

TECHNICAL CHALLENGE/ SUBPROJECT LEVEL

Command and Control
<TC-C2>
Subproject Manager (SPM)
Mike Jarrell, GRC
Subproject Technical Leads
Jim Griner, GRC

TECHNICAL WORK PACKAGE LEVEL

- **SATCOM**
- **Terrestrial Extension**
- **Integrated Flight Test Support (IT&E TWP)**

SCHEDULE PACKAGE LEVEL

C2 Performance Standards

Research and Develop C2 Prototype System

Conduct C2 Flight Test and MS&A
Data Link
CNPC Spectrum
CNPC Security
BVLOS/BRLOS
ATC Interoperability

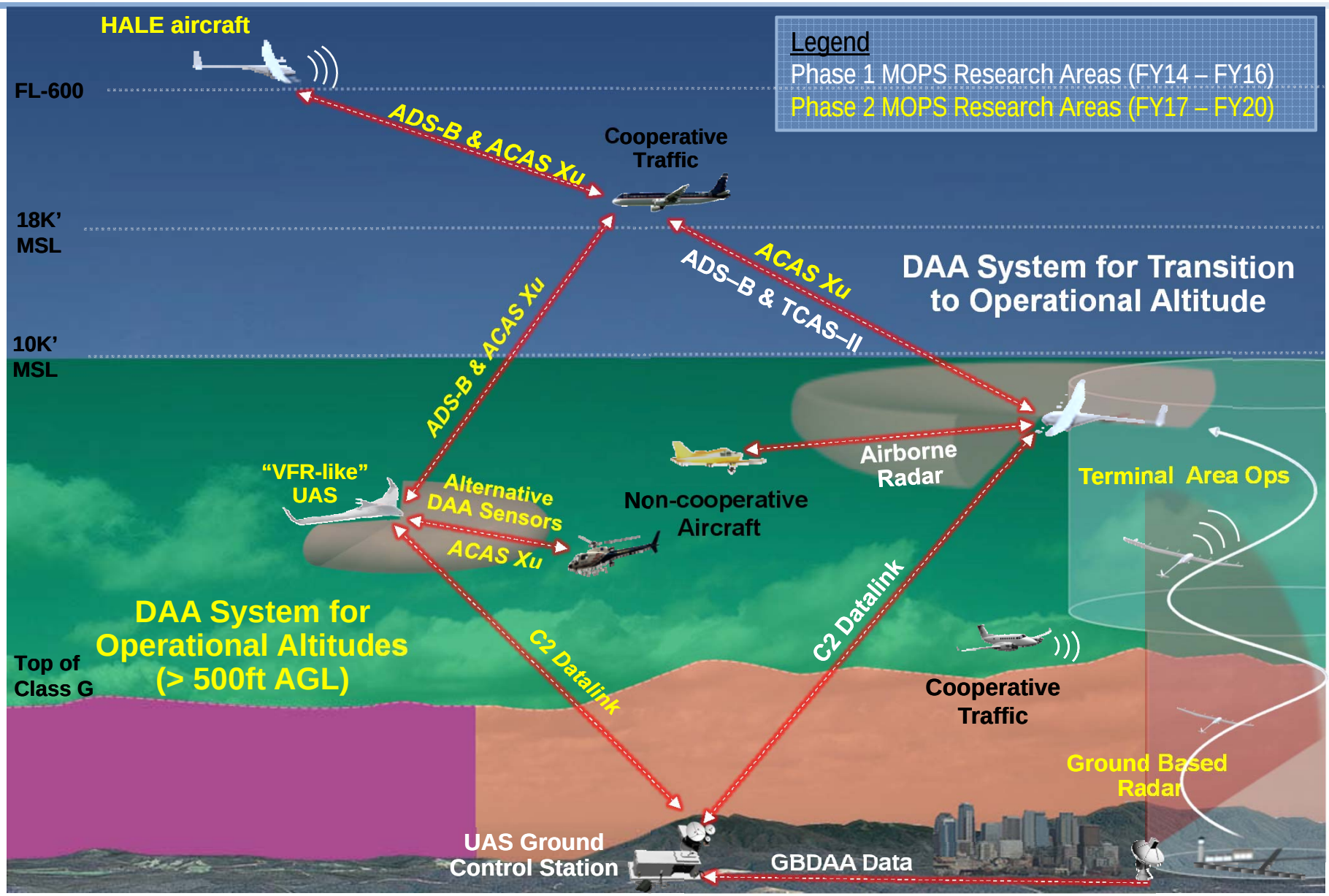
Develop C2 Requirements

C2 Performance Requirements to inform C2 MOPS

RTCA
C2 MOPS

C2 Technical Standard Order (TSO)

UAS-NAS Detect and Avoid (DAA) Operating Environments (OE)



DAA Subproject Structure for Project Phase 2

TECHNICAL CHALLENGE/ SUBPROJECT LEVEL

Detect and Avoid

<TC-DAA>

Subproject Manager (SPM)

Jay Shively, ARC

Subproject Technical Leads

Gilbert Wu (A)/Confesor Santiago, ARC; Lisa Fern; ARC; Tod Lewis, LaRC

TECHNICAL WORK PACKAGE LEVEL

- **Alternate Surveillance Requirements**
- **Well Clear Alerting Requirements**
- **ACAS Xu**
- **External Collaborations**
- **Integrated Events**

SCHEDULE PACKAGE LEVEL

SAA Performance Standards

Develop DAA Test beds

Conduct SAA Flight Test and MS&A

Human Factors
Performance Trade-offs
Interoperability
Self Separation
CONOPs
Well Clear
Collision Avoidance

Develop SAA Performance & Interoperability Requirements

SAA Performance Requirements to inform DAA MOPS

RTCA **DAA MOPS**

SAA Technical Standard Order (TSO)

IT&E Subproject Structure for Project Phase 2

TECHNICAL CHALLENGE/ SUBPROJECT LEVEL

Integrated Test & Evaluation

<TC-ITE>

Subproject Manager (SPM)

Mauricio Rivas, AFRC (A) /Jim Murphy, ARC (A)

Subproject Technical Leads

Ty Hoang, ARC (A) ; Sam Kim, AFRC

TECHNICAL WORK PACKAGE LEVEL

- **Integration of Technologies into LVC-DE**
- **Simulation Planning & Testing**
- **Integrated Flight Test**

SCHEDULE PACKAGE LEVEL

Integrated Test & Evaluation

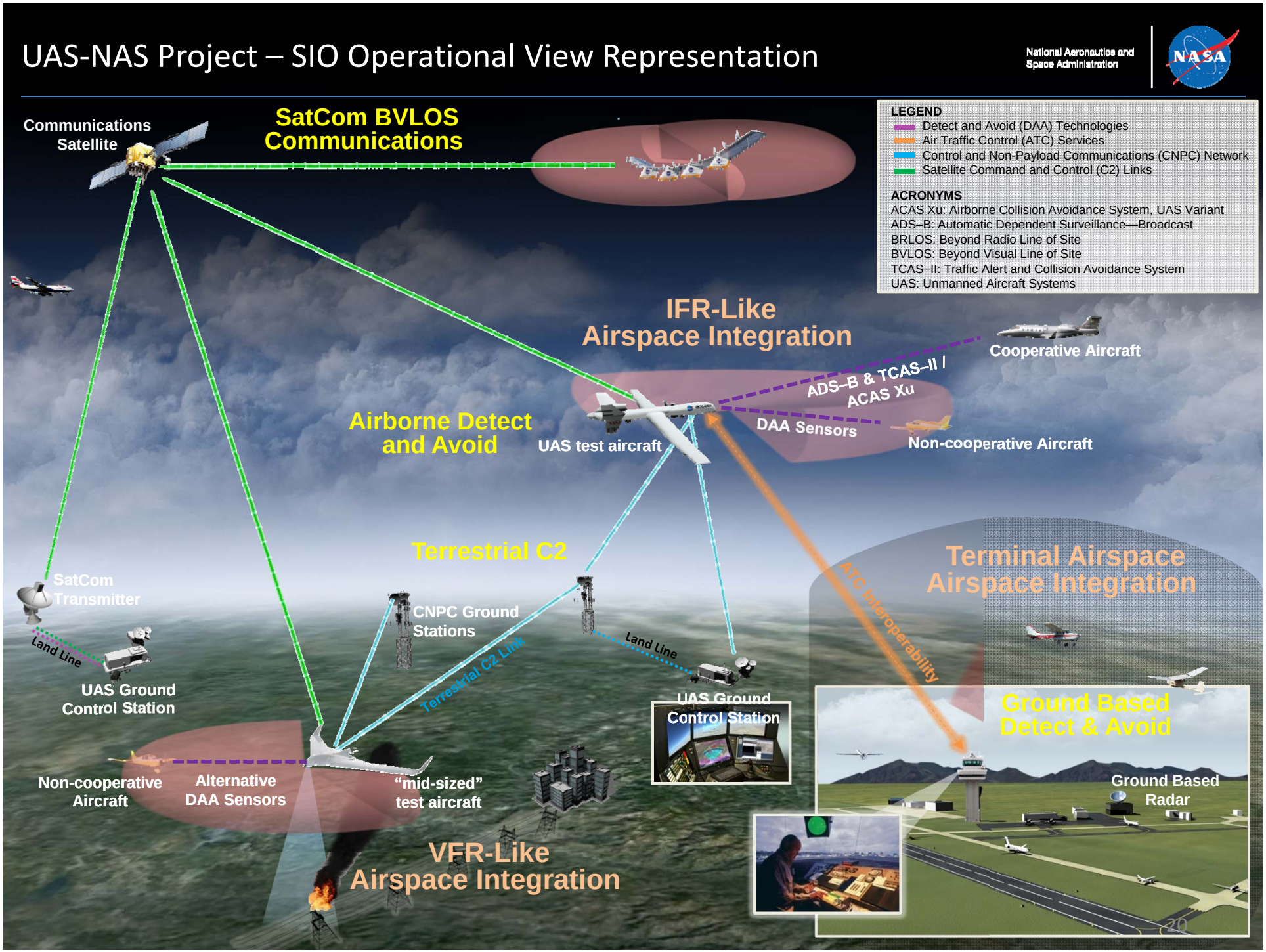
Develop DAA Prototype System → **Live Virtual Constructive (LVC) Test Infrastructure** → **Conduct Technology and CONOPS testing**

Re-usable Test Infrastructure

- **ACAS Xu FT2**
- **No Chase COA**
- **Conduct FT5 Test Scenarios**
- **Conduct FT6 Test Scenarios**

UAS-NAS Project – SIO Operational View Representation

National Aeronautics and Space Administration

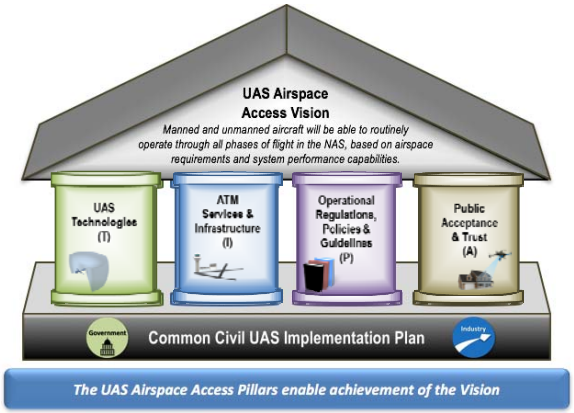


SIO Notional Objectives and Scope

- Primary Objectives
  - Demonstrate robust UAS operations in the NAS by leveraging integrated DAA, C2, and state of the art UAS technologies with a pathway towards certification to inform FAA UAS integration policies and operational procedures
  - Validation that project research is applicable to SIO UAS partner mission aircraft level functional and operational performance criteria
  - Enable at least one broadly applicable set of UAS mission scenarios
  - Develop generic type certification basis consistent with SIO UAS partner missions
  - Advance the state of the art for UAS vehicle technologies while simultaneously accelerating the timeline for UAS integration

- Scope:
  - UAS Integration focused demonstration flight(s) with one or more partner provided UAS
  - Considers all ground and flight needs necessary to implement the proposed UAS mission (e.g. all phases of flight, take-off through landing, etc)
  - All UAS equipped with operationally relevant, DAA and C2 systems that have a pathway to certification (not necessarily SC-228 developed standards)
  - All vehicle technologies assessed to determine the most state of the art solution set that can meet airworthiness expectations for the demonstration
  - Operating Environment is MOPS-like, with primary operating altitude being above 500ft (i.e IFR-Like, and VFR-like) - Operating environment applicable across P1 & P2 MOPS development will be assessed to determine the most broadly applicable and operationally ready UAS

NASA/FAA/Industry Relationship for SIO



Maximum contribution from NASA

NASA

- C2 and DAA Technologies
- UAS Airworthiness
- ARMD-wide Technologies
- Generic Type Cert Basis

UAS Int. RTT

DAA/C2, RFI/RFP

SIO

FAA role TBD

FAA

- Approval to fly in the NAS
- Procedural / policy / regulatory changes

TSOs, Ops Approval

Industry

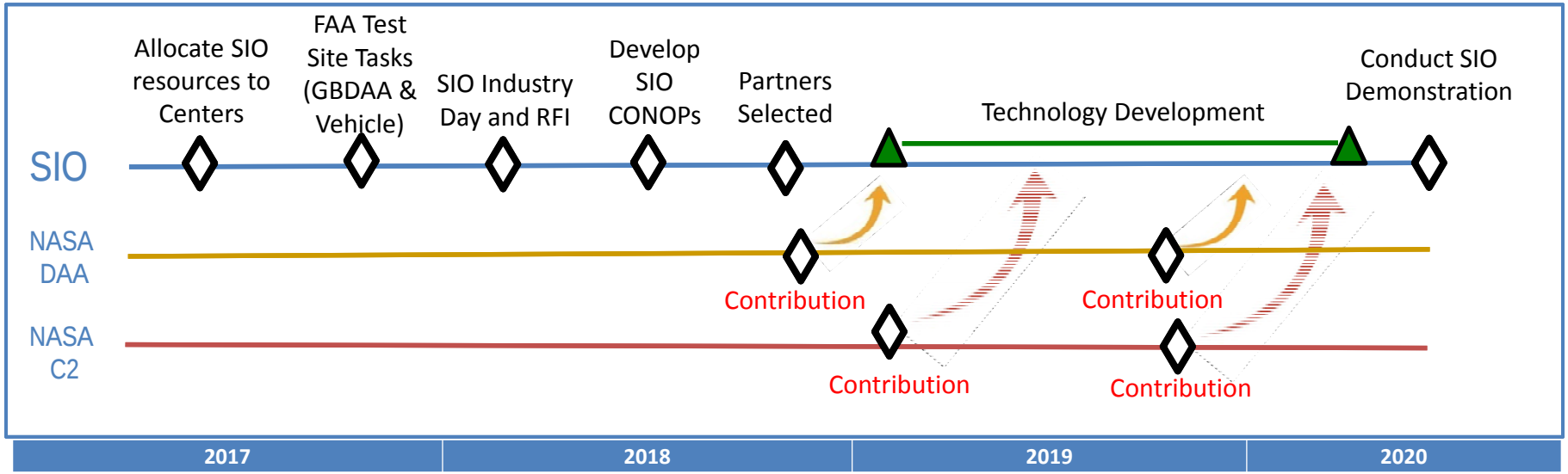
- Airworthy vehicle with integrated C2 and DAA equipage
- Other gap filling technologies required
- Specific Type Cert Basis

Minimum contribution from Industry

Systems Integration and Operationalization (SIO) Partnership Venn

SIO Notional Demonstration Strategy

SIO Potential Stakeholders	SIO Potential Partners	SIO Engagement Strategy
• RTCA SC-228 • FAA • ICAO, EUROCAE	• Industry Aircraft OEMs • Industry Sensor Manufacturers • Industry Communications Provider • FAA UAS Test Sites • AFRL, US Army • Service Providers	Industry Partnership Strategy • Develop an RFP with substantial industry investments, and leveraging NASA SMEs, to conduct the SIO demonstration • Industry to integrate/develop C2 and DAA technologies in concert with essential vehicle technologies • Conduct industry centric SIO demonstration FAA Partnership Strategy • Work through the UAS Integration RTT to impact policy/procedural/regulatory/approval changes



SIO Notional Success Criteria / RFP Considerations

SIO Success Criteria Considerations	Description of Considerations
Command and Control / Detect and Avoid	Criteria developed around leveraging industry to integrate C2 and DAA technologies with a pathway to certification. Full success considers leveraging SC-228 “compliant” DAA and C2 in combination with other essential elements of DAA (i.e autonomy, V2V, etc), C2 (i.e Satcom/LTE), and GCS (including transmitting/receiving DAA messages through the CNPC link) as required by Conops to demonstrate a functional and integrated system
Vehicle Technologies	Criteria developed around a robust set of vehicle technologies that allow industry to safely perform their mission. Full success considers innovative nature of the technologies, and potential for applicability across a broad set of missions.
Operational Environment	Criteria developed around a flight test that demonstrates all ground and flight needs (e.g. all phases of flight, take-off through landing, etc.) in realistic operating environment. Full Success would involve multiple operational environments and Urban Air Mobility
Aircraft Type	Criteria developed around the minimum requirements to perform the test on a UAS (or optionally piloted vehicle if safety case mandates). Full Success would involve multiple UAS.
Test Location	Criteria developed around considerations for the test location (i.e. controlled access locations such as Test Sites) as the minimum. Full success progresses from Test Site test locations to the an appropriately equipped NAS operating environment (e.g. Dallas Tx).
Other	Criteria developed around NASA connectivity and security (i.e. LVC-DE), timeframe, business case, industry partners matching funds, safety, etc.

Upcoming SIO RFI and Industry Day

- Goal of RFI / Industry Day Process
  - Obtain Technical information on relevant industry efforts such as technology development cycles and overall plans for UAS commercialization
  - Obtain schedule related information to determine 2020 SIO date is feasible
  - Obtain reasonalbe ROMs from Industry to ensure SIO is a feasible solution, and guide contracting decision
  - Foster coordination across industry participants and potential proposal teams

- Status of RFI
  - Scheduled to be released in early October
  - Includes plans for simultaneous announcement of industry day for December 14, 2017 in San Diego
  - Responses required by mid-late December 2017

Test Site GBDAA and Vehicle Task Overviews

- Tasks were designed to:
  - Push the community forward on Ground Based Detect and Avoid Standards and round out investments on the NASA DAA Technical Challenge
  - Push future goals of SIO onto the Test Sites, and affiliated UAS industry
  - Understand and assess the community state of the art on GBDAA and certification of UAS vehicles and integration of DAA and C2.

GBDAA Task Background and Overview

- Background
  - UAS-NAS needs to evaluate/assess the readiness of essential industry technologies for the 2020 SIO demonstration
  - The GBDAA task will guide NASA in determining technology components and prioritization for the SIO demonstration

- Objectives
  - The awardee test site(s) will develop and characterize a GBDAA system, deliver sensor models to NASA, and participate in RTCA SC-228

- NASA is evaluating the following before making an award:
  - GBDAA Concept of operations, architecture development, and feasibility assessment
  - NASA LVC-DE Authority To Operate
  - Characterize GBDAA sensors and relevant system components
  - Implementation of GBDAA System
  - Additional considerations

- Award Winner:
  - TBD

Vehicle Task Background and Overview

- Background
  - UAS-NAS needs to evaluate/assess the readiness of essential industry technologies for the 2020 SIO demonstration
  - This vehicles technology demonstration task will guide NASA in determining technology components and prioritization for the SIO demonstration

- Objectives
  - The awardee test site(s) will assess individual vehicle technology state of the art for a test site defined ConOps
  - The awardee test site(s) will perform state of the art vehicle demonstrations across one or more of the four UAS OEs
  - NASA is particularly interested in the Urban operating environment.

- NASA is evaluaing the following before making an award:
  - ConOps Development and Technology Relevance Description
  - Design Requirements and Safety Case Development specific to ConOps
  - Feasibility of Implementable C2 and DAA solutions
  - Vehicle Technologies Demonstration
  - Strength of Partnerships
  - Achievable Schedule

- Award Winner:
  - TBD

Summary

- NASA has developed, and is executing, a Cohesive Strategy for UAS Integration

- NASA is dedicated to partnering with industry to develop robust DAA and C2 technologies in collaboration with RTCA SC-228

- NASA is moving towards a Systems Integration and Operationalization demonstration in partnership with industry
  - Industry will integrate critical technologies onto a UAS, develop broad vehicle technologies, and work towards type certification
  - NASA will complement industry technology development gaps in DAA, C2, and generalize the type certification efforts
  - NASA and Industry will work with the FAA to ensure appropriate approvals and policies benefit the entire industry

Questions?

Davis Hackenberg

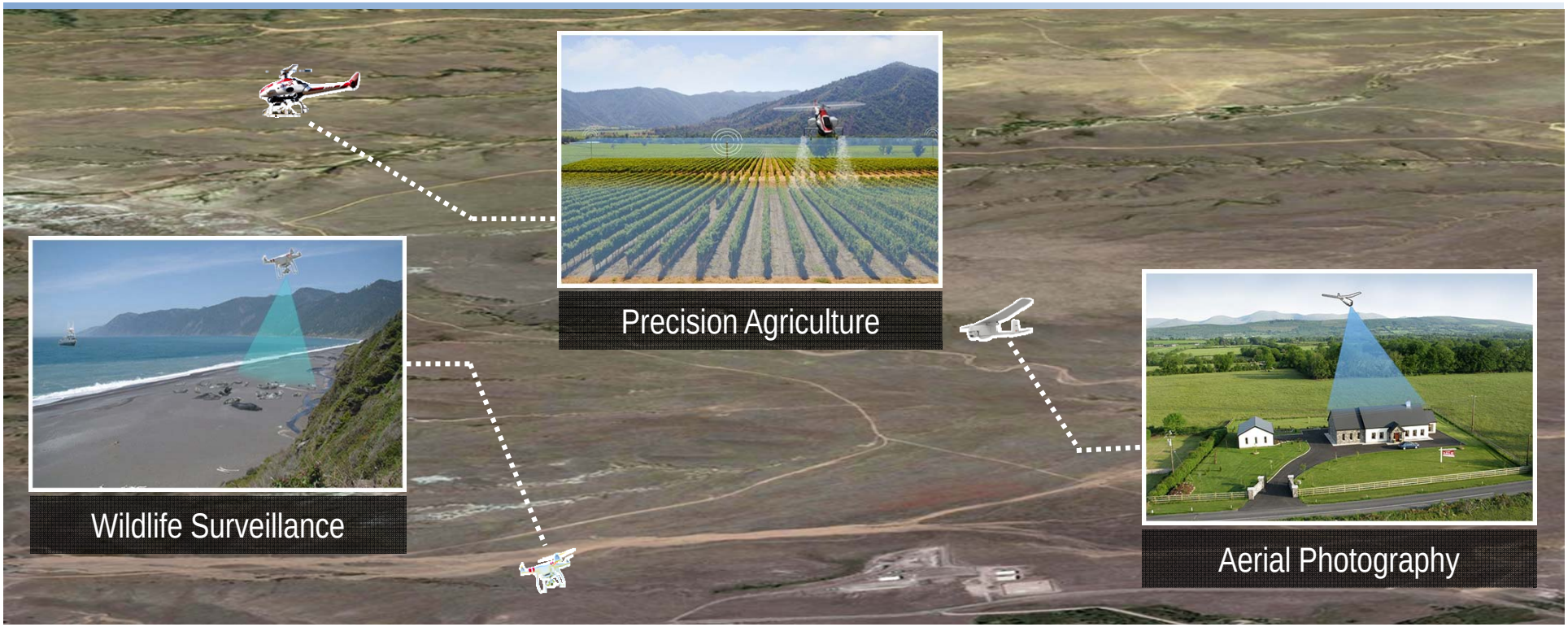
Deputy Project Manager

davis.l.hackenberg@nasa.gov

BACK-UP

UAS Demand

Low Altitude Rural Operations



Demand Drivers:

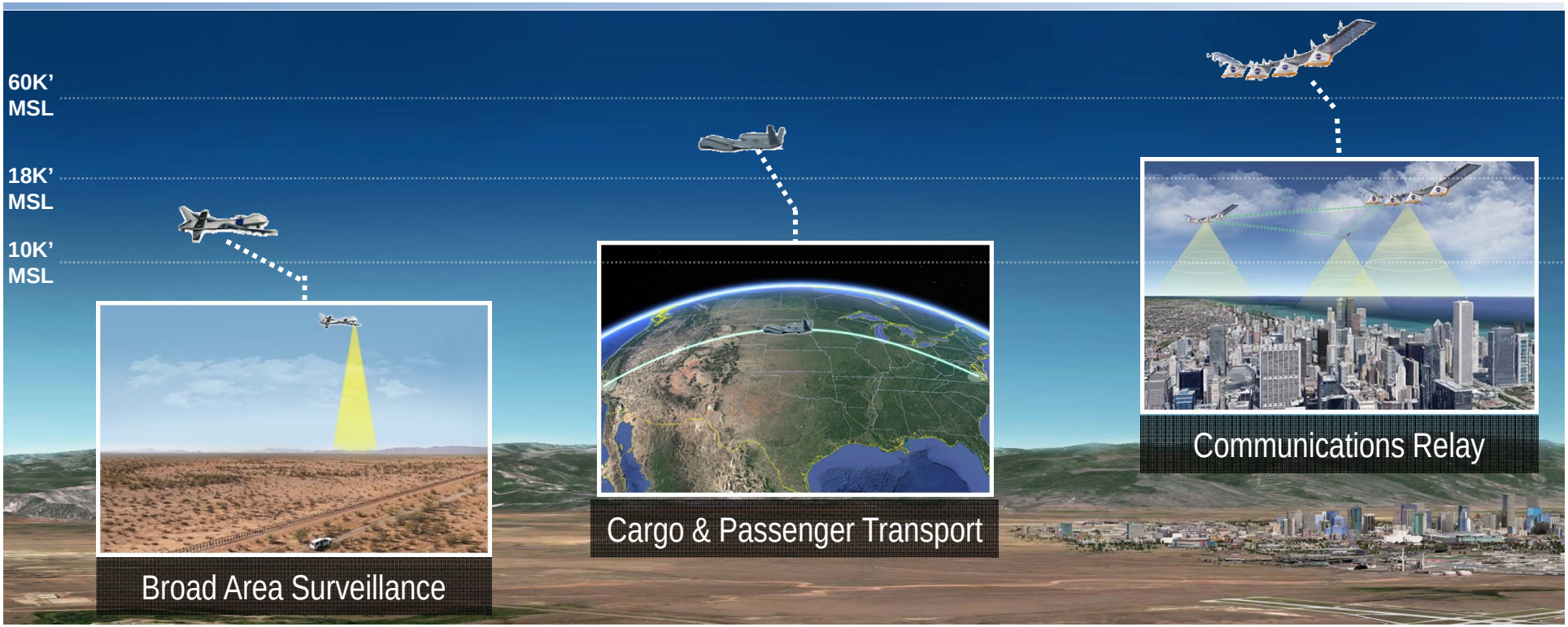
- There is a significant demand for visual line of sight flights to conduct precision agriculture, photography, and surveillance missions. This has been evident through the FAA's incremental approval process from COAs to Section 333 to 14CFR Part 107.
- The demand for these missions to expand the approval envelope to include operations beyond visual line of sight has been increasing.

Representative Markets / Companies:

- Precision Agriculture (PrecisionHawk, Elbit)
- Wildlife Surveillance (NWF, Fish & Game)
- Aerial Photography (GoPro, Roofing, Real Estate)
- Remote Surveillance (Pipelines, Railroads, Power lines, Mining)
- Vertical Infrastructure (Oil /Gas refineries, Bridges)

UAS Demand

IFR-Like Operations



Demand Drivers:

- Beyond DoD, many organizations (e.g. DOI, NOAA, NASA, FedEx, DHL) have expressed an interest in using IFR-Like operations for surveillance, science, and cargo delivery missions.
- Industry is also very interested in using HALE UAS as a more reliable option to satellite communications for remote parts of the globe.

Representative Markets / Companies:

- Communications Relay (Facebook, Google, AeroVironment)
- Cargo & Passenger Transport (FedEx, DHL, Medical Supply, Thin Haul)
- Broad Area Surveillance (DOI, DHS)
- Weather Monitoring (NOAA, NASA)
- Emergency Response & Assessment (Land Management, FEMA, Insurance)

UAS Demand

Low Altitude Urban Operations

Demand Drivers:

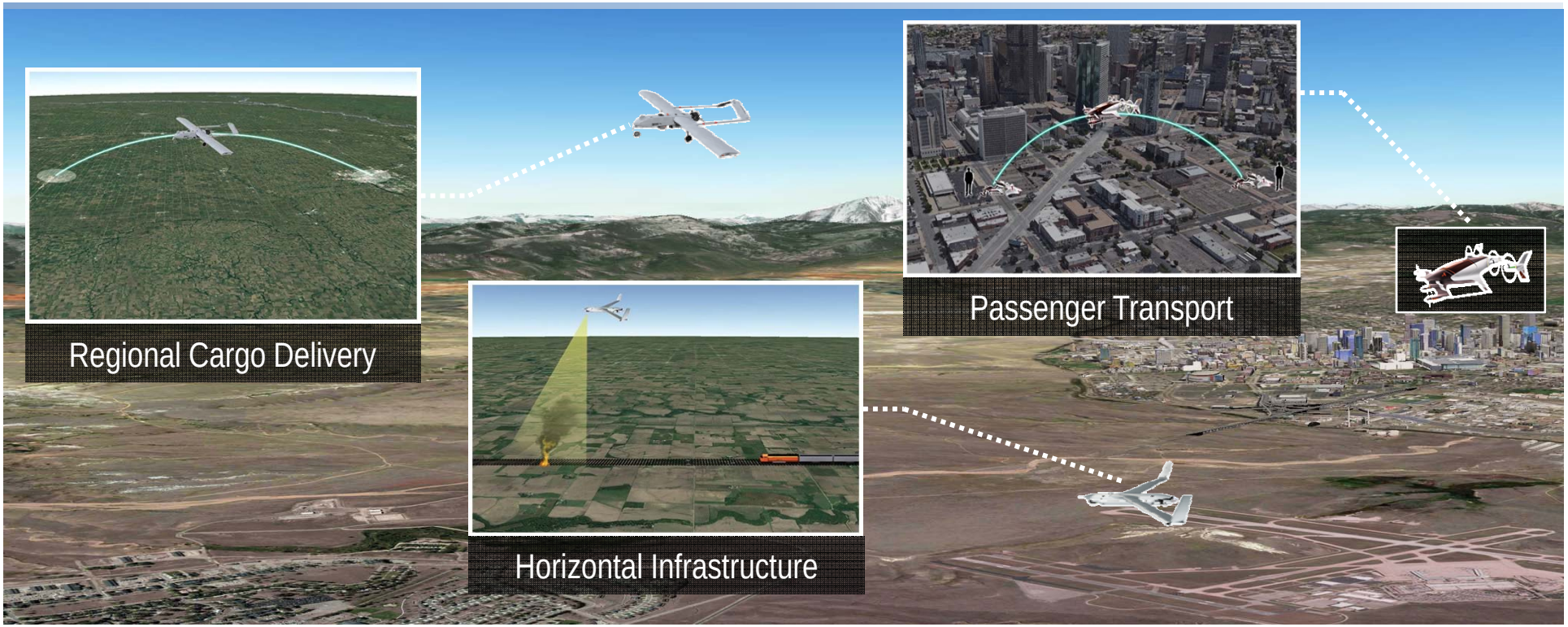
- The most prominent example of UAS demand has been in the package delivery trade space. Amazon, Google, Walmart, and others have plans to use the low altitude volume of airspace for on-demand, door-to-door delivery of goods.
- Several public service applications exist such as news gathering, traffic monitoring and photogrammetry.

Representative Markets / Companies:

- Local Package Delivery (Amazon, Walmart)
- Traffic Monitoring (Local News Stations, Waze)
- Search and Rescue (Law Enforcement, First Responders)
- Infrastructure Surveillance & Protection (Airports, Stadiums, Prisons, DHS CBP)
- Construction Site Monitoring (Land developers, Tax Assessment)

UAS Demand

VFR-Like Operations



Demand Drivers:

- Demand for VFR-Like UAS will largely depend on their ability to establish a business case that is competitive with many existing manned aircraft operations.
- Beyond Visual Line of Site (BVLOS) operations for horizontal infrastructure inspection, regional package delivery and transportation of people are current markets for this class of vehicle.

Representative Markets / Companies:

- Horizontal Infrastructure (Railways, Exxon Mobil, Duke Energy)
- Regional Cargo Delivery (Amazon, Walmart)
- Personal Transportation (Uber, AIRBUS, Ehang)
- Humanitarian Studies (Red Cross, Health Dept.)
- Wildfire Monitoring (Fire Rescue, State/Local Authorities)