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 Mission Directorate

Human Exploration and Operations Mission Directorate

Science Mission Directorate

Space Technology Mission Directorate

Aerospace Research Mission Directorate

Human Exploration and Operations Mission Directorate

Space Technology Mission Directorate

Ames Research Center

Armstrong Flight Research Center

Jet Propulsion Laboratory

Johnson Space Center

Stennis Space Center

Marshall Space Flight Center

Goddard Space Flight Center

Langley Research Center

Kennedy Space Center

Glenn Research Center

NASA Headquarters

Ames Research Center

Armstrong Flight Research Center

Jet Propulsion Laboratory

Johnson Space Center

Stennis Space Center

Marshall Space Flight Center

Goddard Space Flight Center

Langley Research Center

Kennedy Space Center

Glenn Research Center

NASA Headquarters
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

Davis Hackenberg
Deputy Project Manager
**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*
These UAS will operate at altitudes below critical NAS infrastructure and will need to routinely integrate with both cooperative and non-cooperative aircraft. *(Example Use Case: Infrastructure Surveillance)*

UAS will be expected to meet certification standards and operate safely with traditional air traffic and ATM services. *(Example Use Case: Communication Relay / Cargo Transport)*

须与受控的航空交通环境以及在不受控的空域安全运行。*(Example Use Case: Traffic Monitoring / Package Delivery)*
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 Mgmt 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

_**UAS Airspace Access Vision**_
Manned and unmanned aircraft will be able to routinely operate through all phases of flight in the NAS, based on airspace requirements and system performance capabilities.

**Operational Regulations, Policies & Guidelines:**
- P01 - ATM Regulations / Policies / Procedures
- P02 - Airworthiness Regulations / Policies / Guidelines
- P03 - Operating Rules / Regulations / Procedures
- P04 - Safety Risk Mgmt & 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
• 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

September 26, 2017

UAS INTEGRATION IN THE NAS

Davis Hackenberg
Deputy Project Manager
UAS-NAS Phase 2 (other acting)
Project Organization Structure

**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 Johnons, 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
  - Irma Ruiz, AFRC
- Scheduler
  - Jamie Turner, AFRC
- Risk Manager/Outreach
  - Lexie Brown, AFRC
- Change/Doc. Mgmt
  - Sarah Strahan, AFRC
- Admin Support
  - TBD, 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, AFRC
- C2 Technical Integration Lead for SIO
  - TBD, GRC

**Subproject Levels**

- **Detect and Avoid (DAA)**
  - Subproject Manager
    - Jay Shively, ARC
  - Subproject Technical Lead
    - Gilbert Wu (A)/Confesor Santiago, ARC; Lisa Fern; ARC; Tod Lewis, LaRC

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

- **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)

Technical Challenge-C2: Command and Control (C2)

Systems Integration and Operationalization (SIO)
## NASA UAS-NAS Project Activities

### C2 Performance Standards
- **Research C2 SATCOM Systems**
- **Develop C2 Prototype Terrestrial System**
  - Conduct C2 Flight Test and MS&A
    - Data Link
    - CNPC Spectrum
    - CNPC Security
    - BVLOS/BRLOS
    - ATC Interoperability
  - Develop C2 Requirements

### DAA Performance Standards
- **Develop DAA Test beds**
  - Conduct DAA Flight Test and MS&A
    - Human Factors
    - Performance Trade-offs
    - Interoperability
    - CONOPS
    - Well Clear
    - Collision Avoidance
    - Self Separation
    - Low Cost SWaP sensors
  - Develop DAA Performance & Interoperability Requirements

### Integrated Test & Evaluation
- **Develop DAA Prototype System**
  - Live Virtual Constructive (LVC) Test Infrastructure
  - Conduct Technology and CONOPS testing
  - ACAS Xu FT2
  - No Chase COA
  - Conduct FT5 Test Scenarios
  - Conduct FT6 Test Scenarios

### Systems Integration and Operationalization
- **Develop Robust NASA/Industry Partnership**
- **Develop Generic (NASA) and Specific (industry Type Cert Basis)**
- **Integrate Essential Technologies**
- **FAA Approval**
- **Conduct Demo**

### Key Products
- SATCOM MOPS
- Terrestrial MOPS
- Non-Coop Sensor MOPS
- GBDAA MOPS
- DAA MOPS Rev A/B

### Resultant Outcomes
- C2 Performance Requirements to inform C2 MOPS
- DAA Performance Requirements to inform DAA MOPS
- Re-usable Test Infrastructure
- Substantiated path to certification
- FAA Approval
- Conduct Demo
- Type Certification Basis

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**UAS-NAS Project Value Proposition**

**NASA UAS-NAS Project Activities**

**Key Products**

**Resultant Outcomes**

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

Legend
Phase 1 MOPS Research Areas (FY14 – FY16)
Phase 2 MOPS Research Areas (FY17 – FY20)

SATCOM C2 Data Link
Communications Satellite
C-band SATCOM Link
SARCOM/BLOS Link
Terrestrial C2 Data Link

15K’ MSL
10K’ MSL
FL-600

Cooperative Traffic
Non-cooperative Traffic

“VFR-like” UAS
“IFR-like” UAS

Top of Class G

Satellite Transmitter
Terrestrial C2 Data Link

UAS Ground Control Station
CNPC Network

Cooperative Traffic
C2 Subproject Structure for Project Phase 2

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

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

**C2 Performance Standards**
- Research and Develop C2 Prototype System
- Conduct C2 Flight Test and MS&A
  - Data Link
  - CNPC Spectrum
  - CNPC Security
  - BVLOS/BLOS
  - 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)

Legend
Phase 1 MOPS Research Areas (FY14 – FY16)
Phase 2 MOPS Research Areas (FY17 – FY20)

DAA System for Operational Altitudes (> 500ft AGL)

HALE aircraft

18K’ MSL

10K’ MSL

Top of Class G

DAA System for Transition to Operational Altitude

Cooperative Traffic

Non-cooperative Aircraft

Airborne Radar

Terminal Area Ops

Ground Based Radar

Cooperative Traffic

UAS Ground Control Station

GBDAA Data

Legend

Phase 1 MOPS Research Areas (FY14 – FY16)
Phase 2 MOPS Research Areas (FY17 – FY20)
DAA Subproject Structure for Project Phase 2

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

Alternate
Surveillance
Requirements

Well Clear
Alerting
Requirements

ACAS Xu

External
Collaborations

Integrated Events

SAA Performance Standards

Develop DAA Test beds

Conduct SAA Flight Test and MS&A
Human Factors Performance Trade-offs 
Interoperability Self Separation

Develop SAA Performance & Interoperability Requirements

SAA Performance Requirements to inform DAA MOPS

RTCA DAA MOPS

SAA Technical Standard Order (TSO)
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

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

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
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

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

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

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

**SIO**
- TSOs, Ops Approval

**Systems Integration and Operationalization (SIO) Partnership Venn**

- Maximum contribution from NASA
- FAA role TBD
- Minimum contribution from Industry
# SIO Notional Demonstration Strategy

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

<table>
<thead>
<tr>
<th>Year</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
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<tbody>
<tr>
<td>FAA Test Site Tasks (GBDAA &amp; Vehicle)</td>
<td>SIO Industry Day and RFI</td>
<td>Develop SIO CONOPS</td>
<td>Partners Selected</td>
<td>Technology Development</td>
</tr>
<tr>
<td>Allocate SIO resources to Centers</td>
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<tr>
<td>SIO</td>
<td>NASA DAA</td>
<td>NASA C2</td>
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Contribution

Contribution

Contribution

Contribution
<table>
<thead>
<tr>
<th>SIO Success Criteria Considerations</th>
<th>Description of Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command and Control / Detect and Avoid</td>
<td>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.</td>
</tr>
<tr>
<td>Vehicle Technologies</td>
<td>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.</td>
</tr>
<tr>
<td>Operational Environment</td>
<td>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</td>
</tr>
<tr>
<td>Aircraft Type</td>
<td>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.</td>
</tr>
<tr>
<td>Test Location</td>
<td>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).</td>
</tr>
<tr>
<td>Other</td>
<td>Criteria developed around NASA connectivity and security (i.e. LVC-DE), timeframe, business case, industry partners matching funds, safety, etc.</td>
</tr>
</tbody>
</table>
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 reasonable 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 evaluating 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?

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BACK-UP
**UAS Demand**

*Low Altitude Rural Operations*

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**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)
**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)
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)
**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)