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
Airspace Operations and Safety Program

Advanced Air Vehicles Program

Integrated Aviation Systems Program

**MISSION PROGRAMS**

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

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

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

**SEEDLING PROGRAM**

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

Transformative Aeronautics Concepts Program
NASA ARMD
Cohesive UAS Integration Strategy
**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 will be expected to meet certification standards and operate safely with traditional air traffic and ATM services. (Example Use Case: Communication Relay / Cargo Transport)

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)

Low risk BVLOS rural operations with or without aviation services. (Example Use Case: Agriculture)

Must interface with dense controlled air traffic environments as well as operate safely in uncontrolled airspace. (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

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
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.

Game Changing Technologies (Revolutionary)

Foundational Aviation Technologies

Next Era of Aviation

Transitional Aviation Advancements

More Efficient
Shorter Wait times
Increased Capacity

Self Learning Cognition
Supersonics
Adaptive Autonomy
Electric Aircraft

Detect & Avoid
BVLOS C2
RF Spectrum
Hazard Avoidance
Cybersecurity
Noise
Weather
UTM
Flight & Health Management

Systematic Technology Development (Evolutionary)
Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project Overview
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 Johnsons, AFRC
- Staff Engineer Dan Roth, AFRC
- Lead Resource Analyst April Jungers, AFRC
- Resource Analysts Amber Gregory, AFRC
  - Warquiel 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

**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**

**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
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)
UAS-NAS Project Value Proposition

**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**
- C2 Performance Requirements to inform C2 MOPS
- DAA Performance Requirements to inform DAA MOPS
- Re-usable Test Infrastructure

**Resultant Outcomes**
- C2 Technical Standard Order (TSO)
- DAA Technical Standard Order (TSO)
- Substantiated path to certification
- Type Certification Basis
- SATCOM MOPS
- Terrestrial MOPS
- Non-Coop Sensor MOPS
- GBDAA MOPS
- DAA MOPS Rev A/B
- RTCA
- RTCA
- RTCA
- RTCA
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
Terrestrial C2 Data Link
Cooperative Traffic
Ku/Ka SATCOM Link
"IFR-like" UAS

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

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

DAA System for Transition to Operational Altitude

HALE aircraft

“VFR-like” UAS

DAA System for Operational Altitudes (> 500ft AGL)

Non-cooperative Aircraft

Cooperative Traffic

Airborne Radar

Terminal Area Ops

Ground Based Radar

Cooperative Traffic

C2 Datalink

UAS Ground Control Station

GBDAA Data

Legend
Phase 1 MOPS Research Areas (FY14 – FY16)
Phase 2 MOPS Research Areas (FY17 – FY20)
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
Con Ops
Well Clear
Collision Avoidance

SAA Performance Requirements to inform DAA MOPS

RTCA
DAA MOPS
SAA Technical Standard Order (TSO)
Integrated Test & Evaluation

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
UAS-NAS Project – SIO Operational View Representation

LEGEND
- Detect and Avoid (DAA) Technologies
- Air Traffic Control (ATC) Services
- Control and Non-Payload Communications (CNPC) Network
- Satellite Command and Control (C2) Links

ACRONYMS
- ACAS Xu: Airborne Collision Avoidance System, UAS Variant
- ADS-B: Automatic Dependent Surveillance—Broadcast
- BRLOS: Beyond Radio Line of Site
- BVLOS: Beyond Visual Line of Site
- TCAS-II: Traffic Alert and Collision Avoidance System
- UAS: Unmanned Aircraft Systems

Communications
SatCom BVLOS Communications

IFR-Like Airspace Integration
Cooperative Aircraft

Terrestrial C2

SatCom BVLOS Communications

Non-cooperative Aircraft

SatCom Transmitter

LAND LINE

UAS Ground Control Station

Terrestrial C2 Link

Non-cooperative Aircraft

Alternative DAA Sensors

"mid-sized" test aircraft

VFR-Like Airspace Integration

Airborne Detect and Avoid

UAS test aircraft

DAA Sensors

Terrestrial C2 Link

UAS Ground Control Station

UAS Ground Control Station

ACRNYS

Ground Based Detec & Avoid

Ground Based Radar

"mid-sized" test aircraft

IFR-Like Airspace Integration

VFR-Like Airspace Integration

SatCom Transmitter

LAND LINE

UAS Ground Control Station
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

**UAS Int. RTT**

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

**Maximum contribution from NASA**

**Minimum contribution from Industry**

**FAA role TBD**
## SIO Notional Demonstration Strategy

<table>
<thead>
<tr>
<th>SIO Potential Stakeholders</th>
<th>SIO Potential Partners</th>
<th>SIO Engagement Strategy</th>
</tr>
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<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>
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<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

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**Diagram:**
- Allocate SIO resources to Centers
- FAA Test Site Tasks (GBDAA & Vehicle)
- SIO Industry Day and RFI
- Develop SIO CONOPS
- Partners Selected
- Technology Development
- Conduct SIO Demonstration

### Timeline:
- 2017
- 2018
- 2019
- 2020
<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 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?

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BACK-UP
 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)