AAM Ecosystem Working Groups (AEWG):

Urban Air Mobility (UAM) Concept of Operations (ConOps)

Airspace Breakout

July 16th, 2020
3:00pm-5:00pm EDT

The UAM vision will only be achievable if everyone benefits

Image Source: NASA UAM Grand Challenge Industry Day
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<td>Nancy Mendonca</td>
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Speakers, Objectives, & Logistics

**Nancy Mendonca, National Aeronautical and Space Administration (NASA)**
Deputy, AAM Mission Office, NASA COR

**Matt Metcalfe, Deloitte**
Managing Director, Future of Aviation

**Sterling Wiggins, Deloitte**
Senior Consultant, Systems Engineering for Government & Public Sector Practice

**Christine Griffin, Deloitte**
Senior Consultant, Systems Engineering for Government & Public Sector Practice

**Dwight DeCarme, Deloitte**
Senior Consultant, Systems Engineering for Government & Public Sector Practice

**Objectives**
- Engage
- Elicit
- Respond

**Scope**
This ConOps “Community Integration” breakout session is designed such that detailed, pillar-related content will be covered.

**Logistics**
**Polling & Questions:** Use Conferences IO ([https://arc.cnf.io/sessions/wq5g/#!/dashboard](https://arc.cnf.io/sessions/wq5g/#!/dashboard))

**Recording:** This meeting is being recorded so it can be accessed at any time for watch back and for those that could not attend today.

Feedback received during the AEWG ConOps sessions will **NOT** be incorporated into Version 1.0 of the UAM ConOps.
Poll
Conferences I/O

Polling is anonymous

Note: Polling is open during the live session only. If you are watching the recorded version and would like to respond offline, please email: UAMConOps@Deloitte.com

Were you able to successfully join the Conferences I/O?

https://arc.cnf.io/sessions/wq5g/#!/dashboard

Please keep Conferences I/O open throughout the duration of this presentation

Image Source: NASA UAM Grand Challenge Industry Day
Poll

Stakeholder Classification

Polling is anonymous

In which stakeholder group do you classify yourself?

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Poll

ConOps Overview Attendance

Polling is anonymous

Did you attend the UAM ConOps Overview Session on June 25th?

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Poll

ConOps Vehicle Breakout Attendance

Polling is anonymous

Did you attend the UAM ConOps Vehicle Breakout Session on June 26th?

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Poll

ConOps Community Integration Breakout Attendance

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Did you attend the UAM ConOps Community Integration Breakout Session on July 10th?

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Concept Insights & Questions

As the concepts are presented through the course of this presentation, we would like you to keep the following in mind:

Please rate your familiarity with the Draft NASA UAM ConOps

Which of the Airspace unknowns are the highest priority?

Which Airspace concepts require immediate investigation?

Are there any additional high level barriers for the Airspace pillars that should be addressed in this ConOps?

For the Airspace concepts, where would UAM requirements development and maturation benefit you the most?

For the Airspace concepts, what year will UML-4 be realized

For future sessions, should the format and audience size be adjusted to accommodate greater interaction?

Specific questions associated with the concepts within the Airspace pillars and barriers
**Poll**

*Draft NASA ConOps Familiarity*

Polling is anonymous

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**Please rate your familiarity with the Draft NASA UAM ConOps**

[https://arc.cnf.io/sessions/wq5g/#!/dashboard](https://arc.cnf.io/sessions/wq5g/#!/dashboard)

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Airspace System Design & Implementation

Scope and Focus

Design, regulate and manage the airspace and supporting ground facilities to enable safe, efficient and reliable UAM flights in and around metropolitan areas.

Barriers
- Airspace Design
- Operational Rules, Roles, & Procedures
- CNSI & Control Facility Infrastructure
- Vertiport Design
Airspace System Design & Implementation

Barrier: Airspace Design

Develop a practical, feasible, flexible, scalable, implementable, and equitable airspace design and implementation for UAM operations that includes the simultaneous operation of diverse missions and vehicle types (e.g. piloted, autonomous, VTOL, STOL, sUAS) and the placement of vertiports to that takes into account community concerns such as noise and privacy, and consideration for cumulative fleet emissions (e.g., noise, CO2) over local communities.

NASA Community ConOps

- UAM aircraft in the U4-UOE operate in metropolitan areas extending out to the urban periphery.
- Each U4-UOE area is tailored to the unique characteristics of the metropolitan area in which it exists, and can be dynamically adjusted based on FAA criteria.
- The U4-UOE is not a class of airspace itself but exists within other classes of airspace (B, C, D, E, and G). Vehicle operators need to meet the applicable airspace requirements and U4-UOE requirements to operate where U4-UOE exists.
- U4-UOE is managed by Providers of Service to UAM (PSU) through a federated architecture and ATC are aware of UAM operations where there is a possible safety impact on manned traffic.
- To enable high volumes of operations, U4-UOE is designed to include dynamic, demand-based high-density routes for aircraft meeting the performance requirements of the route.
- Redundant emergency landing locations exist for off-nominal events.

Areas with Remaining Unknowns

- Scalability
- U4-UOE Requirements
- Extensions into Actively-controlled Airspace
- Emergency Landing Site Locations
Develop operating rules, roles, procedures and airspace management Concepts of Operation that enable safe and efficient operations and are compatible with urban environments, scalable operations, interoperability, and operations in moderately poor weather operations.

**NASA Community ConOps**

- **Provider of Services to UAM (PSU)** - Flight operations are managed and coordinated by PSUs, which are industry or public sector entities that supply flight safety services under FAA’s regulatory and operational authority to supplement and integrate with manned ATC.
  - PSUs deliver flight planning, communications, and aide in separation along with onboard aircraft sensors. PSUs also ensure there is a common understanding and “picture” amongst PSUs to enable cooperative traffic management.
- **UML-4 UAM Operating Environment (U4-UOE) Network** – PSUs exchange information on the U4-UOE Network. The FAA is able to interface with PSUs in the U4-UOE to push airspace restrictions and constraints to the entire U4-UOE network. These constraints include TFRs and other airspace restrictions.
- **Supplementary Data Service Providers (SDSP)** – SDSPs provide support services to enable UAM operations and may or may not be safety critical.
- **Vehicle Operators** – The vehicle operator is responsible for the operational control of the vehicle, including but not limited to the safe execution of initiating, conducting, and terminating a flight.
- **Flight Crew** – Vehicles have a flight crew consisting or one or more humans who share responsibility for the safety of the flight along with automated systems. This flight crew may be on the vehicle or controlling it remotely.
- **Vertiport Operators** – Vertiport operators are entities responsible for ensuring the safety of individual takeoff and landing areas, as well as any ground services (embarkation, disembarkation, maintenance, etc.) provided at a vertiport.

**Areas with Remaining Unknowns**

- Negotiation Between PSUs
- Single-PSU Regions
- Impact of Dynamic Airspace Management on ATC Workload
- Role of Flight Crew
- Information-sharing Mechanism
Airspace System Design & Implementation

Barrier: Communications, Navigation, Surveillance & Information

Develop and implement in an economically viable manner sufficient, resilient, and secure communication, navigation, surveillance, information (CNSI) and control facility infrastructure, including spectrally-efficient communication links; navigation services including but not limited to GPS; weather surveillance near the ground with high resolution; ability to account for non-cooperative vehicles; and functionality in urban canyons.

NASA Community ConOps

- **Communication** - Vehicle operators maintain communication with PSUs and UAM vehicles (vehicle-to-vehicle) in compliance with performance criteria and regulatory requirements to support data exchange required for safe operations. If the flight crew is off-board the vehicle, that person has the capability of communicating with ATC and controlling the vehicle to comply with ATC instructions.

- **Information** – Secure information exchange enables vehicle-to-vehicle and vehicle-to-infrastructure communication for data exchange, vehicle separation, and navigation.

- **Navigation** - Performance-based navigation (or future performance-based navigation-like) requirements enable dynamic precision trajectory-based operations (TBO), even in visibility-restricted conditions.

- **Surveillance** – UAM CNSI operations are supported by a range of ground, vehicle-borne, and satellite-based infrastructure. While this surveillance information will be utilized by PSUs, it is also anticipated that in some cases direct information exchange can occur between vehicles and between ground/satellite infrastructure to enable vehicle and hazard surveillance by operators and FAA.

- **Cybersecurity** – Requirements for secure communication between elements of the U4-UOE network, the vehicle, and vehicle subsystems ensure secure information exchange and prevent unauthorized intrusion.

Areas with Remaining Unknowns

- On-board Vehicle Situational Awareness
- Sensors Required
- Cybersecurity Requirements
- Available Spectrum
“UAM Operator” includes flight crew in this diagram.
Vertiport locations are strongly influenced by current and future anticipated demand.

Citizens as well as businesses have significant input on vertiport locations as part of the public planning processes.

Zoning ordinances and existing infrastructure can constrain vertiport locations.

Vertiports reflect their environmental constraints including both the climate and the constraints of the specific site.

When planning approach and departure paths, operators plan for trajectories that minimize the impact on local communities.

Vertiports in urban areas contain limited maintenance and repair services while vertiports outside urban centers are designed for expanded aircraft services such as vehicle storage, major repair and overhaul facilities, and serve as intermodal hubs.

Vertiport design includes adequate physical security features to ensure safe and secure operations.

Areas with Remaining Unknowns

- Vertiport Energy Infrastructure
- Vertiport Design Standards
- Repurposing Existing Buildings v. Greenfield Construction
- Minimum Vertiport Facilities
### Key Issues for Further Exploration

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<th>Category Pillar</th>
<th>Key Issues for Further Exploration</th>
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<td>Extensions into Actively-controlled Airspace</td>
<td>Extensions of the UOE into ATC-controlled airspace – How will they be defined and how will they function?</td>
</tr>
<tr>
<td>Scalability</td>
<td>How can the U4-UOE be designed for scalability to enable a high throughput of operations and a variety of vehicle technologies?</td>
</tr>
<tr>
<td>Single-PSU Regions</td>
<td>Will the U4-PSU be layered in a geographic region? Or will they be segmented to accommodate specific geographic regions?</td>
</tr>
<tr>
<td>Impact of Dynamic Airspace Management on ATC Workload</td>
<td>Will the FAA’s ability to dynamically alter airspace in the U4-UOE increase ATC workload?</td>
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<tr>
<td>Role of Flight Crew</td>
<td>What is the role of the human flight crew (onboard or offboard)? What is the division of labor between automation and human? If no human flight crew is necessary how is safe flight achieved?</td>
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<tr>
<td>On-board Vehicle Situational Awareness</td>
<td>What performance capabilities are required for vehicle situational awareness?</td>
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<td>How will spectrum requirements for UML-4 be met?</td>
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Poll
Airspace System Design & Implementation Unknowns

Polling is anonymous

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Which of the Airspace System Design & Implementation unknowns are the highest priority? (select 3)

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Image Source: NASA UAM Grand Challenge Industry Day
Poll
Immediate Investigation
Polling is anonymous

Which Airspace System Design & Implementation concepts require immediate investigation? (select 3)

Thing that are hard to do and are long lead

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Poll

Missing Barriers?

Polling is anonymous

Are there any additional high-level barriers to Airspace System Design & Implementation that should be addressed in this ConOps?

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Image Source: NASA UAM Grand Challenge Industry Day
Airspace & Fleet Operations Management

Scope and Focus

Provide airspace operations management services as well as fleet operations management services that ensure safe, efficient, scalable, and resilient UAM operations in and around metropolitan areas.

Barriers
- Safe Airspace Operations
- Efficient Airspace Operations
- Scalable Airspace Operations
- Resilient Airspace Operations
- Fleet Management
- Urban Weather Prediction
Barrier: Safe Airspace Operations

Develop and implement an airspace operations management system and the corresponding regulations and procedures that enable safe, secure, sustained, resilient, close-proximity, multi-vehicle operations in constrained, urban environments and allow for interoperability of diverse missions and vehicle types, including in off-nominal situations.

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- PSUs provide **deconfliction** by exchanging data across the **U4-UOE network**. This dataset, with elements to be defined by industry consensus and approved by FAA, includes information such as *departure time*, *desired flight path*, *intended arrival destination*, and *alternate vertiports*.
- PSUs provide **pre-flight strategic deconfliction**. **Tactical deconfliction** is largely provided by the vehicle, but with the support of the PSUs for data exchange.
- The PSUs, DAA, and **vehicle-to-vehicle** (V2V) information exchange enables **tactical deconfliction** and **separation assurance** in nominal situations such as maintaining safe separation when following another vehicle or sequencing for landing.
- **Individual aircraft data** assessing both *internal* (vehicle speed, altitude, etc.) and *external environment* (weather, traffic, etc.) is shared via the U4-UOE network with PSUs and SDSPs. Data exchange across the network enables **inflight strategic deconfliction**.
- Due to the time constraints, DAA and potentially *flight crew* or V2V information exchange are the primary means of collision avoidance in situations where *response times need to be in seconds*, such as avoiding flocks of large birds.
- PSUs and other **safety-critical service suppliers** operating in the U4-UOE are **qualified** by FAA based on standards developed and recommended by industry standards development organizations. Non-safety critical SDSPs may also operate on the U4-UOE network with **approval** of FAA.
- Entities **providing data** to or **accessing data** from the U4-UOE network adhere to appropriate **data authentication** and **cybersecurity** standards.
- **Streamlined processes** exist to refine and improve standardized operations and procedures to **continually enhance safety** of UAM operations.

Areas with Remaining Unknowns

- **Industry Safety Standards**
- **Handling Non-cooperative Aircraft**
- **Deconfliction**
### Areas with Remaining Unknowns

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<th>Prioritization and Sequencing Criteria</th>
<th>Performance-based Separation</th>
<th>Access and Equity</th>
<th>Collaboration</th>
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**Barrier: Efficient Airspace Operations**

Develop and implement an airspace operations management system that provides user-preferred routing while allowing equitable, predictable, and on-demand airspace access for diverse missions and vehicle types, including legacy as well as emerging operations.

**NASA Community ConOps**

- Efficient airspace operations can be considered from ***three perspectives***: the **vehicle**, **UAM operations**, and the entire **urban transportation system**.
- **Vehicle efficiency** is summarized as the **time and energy** required to get from **point A to point B**.
  - Enabling vehicle efficiency relies on ***collaboration between the fleet operator and PSU***, strategic and tactical **deconfliction**, **port arrival/departure flexibility**, and **active management** of multiple vehicle types.
- The **number of vehicles** able to safety operate during periods of peak demand reflects **operational efficiency**. Greater **throughput** is enabled by pre-flight **strategic deconfliction**, **reducing separation** between vehicles, and **efficient vertiport** operations.
  - **Prioritization and sequencing criteria** will be developed by UML-4. These **FAA-approved community-based rules**, implemented by PSUs, govern **traffic flow and vehicle order**. This criteria will be **consensus-based** and **prioritize safety** with consideration of the needs of key stakeholders.
  - **Technologies** such as vehicle sensors and real-time data exchange enable **performance-based separation** with comparatively **reduced minimums**.
  - The **number of operations** is primarily driven by **vertiport capacity**. Information exchange between vehicles and infrastructure assists vertiport operators with managing **capacity** at vertiports and prevents the system from being overwhelmed.
- An efficient **urban transportation system** effectively manages demand (which may exceed capacity during peak periods). UAM operations enable an additional avenue to increase the overall urban transportation system capacity.
Many operations occur in dynamic high-density routes within the U4-UOE, which can be modified quickly by PSUs (according to community-based rules) and are supported by air and ground infrastructure needed to support high volumes of air traffic.

Operations along high-density routes are governed by operational procedures that enable sequencing and spacing of vehicles based on the operational characteristics of the vehicle such as airspeed, rate of climb, precision along the center line, and ability to fly in proximity to other vehicles.

Criteria for prioritizing, sequencing, and spacing vehicles will have been established by consensus standards development organizations and approved by FAA. These criteria can be modified by FAA as needed.

Under the principle of airspace equity, any cooperative vehicle that meets U4-UOE performance-based standards has access to these routes.

In the U4-UOE (particularly over cities), air traffic management services are predominantly provided by PSUs, rather than active management by ATC today.

PSU services may extend into ATC-controlled airspace to enable UAM operations through ATC airspace or to landing areas.

These pre-approved, PSU-managed areas and operations enable safe UAM operations without active ATC management.

ATC will maintain the ability to dynamically adjust or close U4-UOE areas (e.g., based on runway configuration changes or emergency situations).
Resiliency in airspace operations is the ability of the system to withstand a major disruption (within parameters) and recover in an acceptable timeframe.

The system has incorporated an In-time Aviation Safety Management System (IASMS) which features monitor, assess, and mitigate functions.

The monitor feature is critical as a control to detect adverse events and operations and includes vehicle health monitoring information and models, aircraft location data to ensure the aircraft is on its approved flight path, comparison of forecasted and actual weather conditions, and systems to identify and track potential non-cooperative traffic.

These and many other features are offered by the PSUs, fleet and vertiport operators, and SDSPs as safety enhancement features and use them as market differentiators.

Redundant systems are a means for the UAM operations to respond appropriately as it utilizes backup systems to continue critical functions while the primary system recovers.

Having more than one PSU within an urban area, pre-identified emergency landing areas, and/or backup communications also improve system resilience.
Management of fleets is largely left to the private sector to develop; however, traffic management is cooperative between PSUs and vehicle operators in the U4-UOE network, which has implications on how vehicle operators choose to manage their fleets.

Local regulators have input into where and when UAM vehicles operate through local vertiport laws and zoning ordinances.

Industry leverages technology applications and new methods for efficiently managing air vehicle fleets and maximizing human productivity.

FAA authorizes traffic management services, industry will provide the services, and operators will coordinate, execute, and manage operations in accordance with accepted standards and practices established by the FAA.
Weather in urban environments is more challenging to characterize than weather outside the urban environment.

Urban environment induced micro-climates cause sharp changes in wind speed and directions at the scales of meters.

Urban heat island effects enhance thermal activity and cause notable changes in density altitude between downtown districts and airports in the suburbs or near large bodies of water.

To achieve an adequate degree of weather resiliency to contribute to reliable and cost-effective operations, a combination of airframe airworthiness improvements, smart siting of vertiports, and a reduction in weather and wind uncertainty caused by urban weather is required.

The weather operations structure is a combination of policy, reporting on current weather conditions, forecasting future weather conditions, information distribution, and decision making.

Arriving at this structure was the result of work by the FAA, National Weather Service, NASA, DOD, the National Science Foundation’s National Center for Atmospheric Research, standards development organizations, industry, trade groups, and universities.
### Airspace & Fleet Operations Management

#### Key Issues for Further Exploration

<table>
<thead>
<tr>
<th>Unknowns</th>
<th>How will the U4-SS network handle non-cooperative aircraft that enter the U4-UOE? How will the associated situational awareness be disseminated to operators in the U4-UOE? Does ATC have a role in such situations?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handling Non-cooperative Aircraft</td>
<td>How will high-density routes be defined? Will they be charted and by whom?</td>
</tr>
<tr>
<td>Selecting and Defining High-density Routes</td>
<td>How will vehicles be prioritized within the U4-UOE? What about for use of high-density routes or specific vertiports? Will prioritization be first come first serve, performance-based, or operator-based?</td>
</tr>
<tr>
<td>Prioritization and Sequencing Criteria</td>
<td>If a prioritization algorithm is used, is there a particular stakeholder or group of stakeholders who will be responsible for developing it?</td>
</tr>
<tr>
<td>Zero-airspeed Collision Avoidance</td>
<td>How will collision avoidance be managed, particularly for vehicles that are hovering or operating at zero airspeed?</td>
</tr>
<tr>
<td>Redundant Systems Impact on Certification Times</td>
<td>How will requiring redundant systems on vehicles impact the time it takes to obtain vehicle certification? How can this be mitigated?</td>
</tr>
<tr>
<td>Weather Sensor Requirements</td>
<td>Will weather sensors be required equipage on vehicles? What additional weather infrastructure is needed to obtain adequate climate information given the unique microclimates that exist in urban areas?</td>
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</table>
Poll

Airspace & Fleet Operations Management Unknowns

Polling is anonymous

Which of the Airspace & Fleet Operations Management unknowns are the highest priority? (select 3)

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Poll
Immediate Investigation
Polling is anonymous

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Which Airspace & Fleet Operations Management concepts require immediate investigation? (select 3)

Thing that are hard to do and are long lead

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Poll

Missing Barriers?

Polling is anonymous

Are there any additional high-level barriers to Airspace & Fleet Operations Management that should be addressed in this ConOps?

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UAM Concept Maturation & Next Steps

The UAM ConOps is a living document that coincides with the maturation of the UAM concept. These concepts and associated documentation will be updated at appropriate intervals. Updates could also align with results from research, test, industry trends, federal/city/state/local policy and regulations, and community input.

### ConOps Version 1.0 Release
- The UAM Community ConOps **Version 1.0 release** is targeted for **Summer of 2020**
- This document will be **released into the public domain** and serve as the “Vision” ConOps for UAM at UML-4

### AAM Ecosystem Working Groups
- Each **AEWG** will address domain specific UAM concepts
- The AEWGs will serve as the **main forum for concept discussion, feedback, and forward work**

### UAM Concept Maturation
- UAM concepts will mature as government, academia, industry, & community coalesce
- As various **UAM activities** are realized, such as research & test, the UAM concepts will be updated
Poll
Requirements
Development

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**For the Airspace concepts, where would UAM requirements development and maturation benefit you the most?**

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UML-4 Realization

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For the Airspace concepts, what year will UML-4 be realized?

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Poll

Future Sessions - Format

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For future sessions, should the format and audience size be adjusted to accommodate greater interaction?

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THANK YOU

This recording and materials can be found on the NARI website in the next few days.