AAM Ecosystem Working Groups (AEWG):

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

Vehicle Breakout

June 26th, 2020
1:30pm-3:00pm EDT

The UAM vision will only be achievable if everyone benefits
# Agenda

**June 26th, 2020**

1:30pm-3:00pm

<table>
<thead>
<tr>
<th>Topic</th>
<th>Content</th>
<th>Presenters</th>
<th>Timing</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welcome Introductions Overview</td>
<td>Rules for the Road Meeting Speakers Vehicle Pillars Overview</td>
<td>Carl Russell Dwight DeCarme</td>
<td>1:30-1:45</td>
<td>0:15</td>
</tr>
<tr>
<td>Concept Deep Dive(s) Interactive Polling</td>
<td>Individual Vehicle Management &amp; Operations Vehicle Development &amp; Production</td>
<td>Brian Hill</td>
<td>1:45-2:45</td>
<td>0:60</td>
</tr>
<tr>
<td>Next Steps Questions</td>
<td>Next Steps Questions</td>
<td>Dwight DeCarme</td>
<td>2:45-3:00</td>
<td>0:15</td>
</tr>
</tbody>
</table>
Speakers

Carl Russell, National Aeronautical and Space Administration (NASA)
RVLT Partnerships Lead, Aircraft/Vehicle AEWG Lead, NASA Ames

Brian Hill, Deloitte
Specialist Master, Systems Engineering for Government & Public Sector Practice

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

Objectives

Engage the community of the detailed UAM concept in the Vehicle pillars

Elicit input regarding industry perceptions, near-term trends, and hurdles pertaining to the Vehicle pillars

Respond to questions regarding detailed Vehicle pillar concepts resident in the ConOps

Logistics

Polling & Questions: Polling will be part of the presentation questions. Use the Conferences IO link (https://arc.cnf.io/sessions/akh3#!/dashboard). Facilitators will answer questions real-time and presenters will answer the most popular questions.

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

Materials: These meeting materials (slides & recording) will be uploaded to the NARI website.

Scope

This ConOps “Vehicle” Breakout session is designed such that detailed, pillar related content will be covered. This session will be more interactive than the overview session with additional polling, real-time questions, and a wrap-up questions/answer session. This is the first breakout in this series and subsequent breakout meetings will address additional UAM pillars and barriers.

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

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

https://arc.cnf.io/sessions/akh3/#!/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?

https://arc.cnf.io/sessions/akh3/#!/dashboard
Poll
ConOps Overview
Attendance

Polling is anonymous

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

https://arc.cnf.io/sessions/akh3/#/dashboard
Urban Air Mobility Community Concept of Operations

“Vision ConOps”
• High-level – Providing a vision of key concepts in the future
• Broad, covering all pillars

Scope
• Passenger-carrying operations
• Vision at the Intermediate state (UML-4)
• Placing air mobility within reach of the general public (i.e., realistic / cost effective transportation choice for general public)
UAM Maturity Levels (UML)

**UML-1**  
**Late-Stage Certification Testing and Operational Demonstrations in Limited Environments**  
Aircraft certification testing and operational evaluations with conforming prototypes; procedural and technology innovation supporting future airspace operations (e.g. UTM-inspired); community/market demonstrations and data collection

**UML-2**  
**Low Density and Complexity Commercial Operations with Assistive Automation**  
Type certified aircraft; initial Part 135 operation approvals; limited markets with favorable weather and regulation; small UAM network serving urban periphery; UTM Construct and UAM routes supporting self-managed operations through controlled airspace

**UML-3**  
**Low Density, Medium Complexity Operations with Comprehensive Safety Assurance Automation**  
Operations include urban core; operational validation of advanced airspace operations and management including UTM inspired ATM, CNSI, C^2, and automation for scalable, weather-tolerant operations; few high-capacity vertiports; noise compatible with urban soundscape; model-local regulations

**UML-4**  
**Medium Density and Complexity Operations with Collaborative and Responsible Automated Systems**  
100s of simultaneous operations; expanded networks including closely-spaced high throughput vertiports; many UTM inspired ATM services available, simplified vehicle operations for credit; low-visibility operations

**UML-5**  
**High Density and Complexity Operations with Highly-Integrated Automated Networks**  
1,000s of simultaneous operations; large-scale, highly-distributed networks; high-density UTM inspired ATM; autonomous aircraft and remote, M:N fleet management; high-weather tolerance including icing; high-volume manufacturing

**UML-6**  
**Ubiquitous UAM Operations with System-Wide Automated Optimization**  
10,000s of simultaneous operations (capacity limited by physical infrastructure); ad hoc landing sites; noise compatible with suburban/rural operations; private ownership & operation models enabled; societal expectation
**Concept Decomposition – UAM Pillars & Barriers**

The 5 UAM Pillars divide the UAM concepts into various high-level categories. These pillars define the major areas of focus for the UAM concept.

### Pillar

The 5 UAM Pillars divide the UAM concepts into various high-level categories. These pillars define the major areas of focus for the UAM concept.

### Barrier

A barrier to realizing the UAM concept. These barriers break out the next level of detail within each pillar. The UAM concept is defined through the details associated with each barrier.

### UAM ConOps Content

These bullets are the detailed, decomposed concepts as they pertain to each barrier. They represent the body of the ConOps and how the concept at UML-4.

### Remaining Unknowns

The unknowns are the areas that require more detail and future research. These unknowns will require further investigation as the UAM concept matures.

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**Individual Vehicle Management and Operations**

**Barrier: Safe Urban Flight Management**

- Develop capabilities for safe, efficient, and accommodating flight planning and execution in metropolitan areas, including navigation performance sufficient for medium complexity operations in urban environments, assuring controlled flight for safe contingency management (including cyber attacks), and compliance with regulations other constraints (such as noise limits).

**NASA Community ConOps**

- **Sufficient actual navigational performance** to operate in metropolitan environments
- **Automation ensures operations occur within a safe operating envelope**
- **Advanced technology such as detect and avoid (DAA) and digital vision enables operations in IMC**
- **Robust navigation systems allow aircraft to operate safely**, even in GPS-degraded/denied operating environments
  - This includes operations around uncooperative obstacles (birds) and aircraft and unplanned obstacles (cranes, antennas, etc.)
- **Advanced vehicle technology** (CNSI, avionics etc.) and vehicle-to-vehicle information exchange allow for performance-based separation

**Areas with Remaining Unknowns**

- Navigational Performance Requirements
- NOTAMs
- CNSI Requirements
- Specific Equipment and DA Technology

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This “vision” ConOps is a **living document** and will continue to be revised as concepts mature through research, development, and UMLs 1-3.
Advanced technologies enable:
• New vehicle configurations
• High performance aircraft
• Efficient propulsion systems
• Greater weather tolerance
• Greater design and production agility

Advanced design and engineering methods (model-based, digital engineering, etc.) along with advanced rapid testing enable more rapid commercialization

Certification process are adapted for new technologies, materials, vehicles and manufacturing process building on the regulatory frameworks in place and enable more rapid incorporation of safety improvements

Mature manufacturing and supply chains, including secure digital processes to track parts and ensure authenticity and traceability, will enable rapid ordering and receipt of parts

For the purposes of this presentation Vehicle = Aircraft
Individual Vehicle Management & Operations Barriers
- Safe Urban Flight Management
- Increasingly Automated Vehicle Operations
- Certification & Ops Approval
- Ground Ops & Maintenance

Vehicle Development & Production Barriers
- Vehicle Design & Integration
- Airworthiness Standards & Certification
- Vehicle Noise
- Weather-Tolerant Vehicles
- Cabin Acceptability
- Manufacturing & Supply Chain
As the concepts are presented through the course of this presentation, we would like you to keep the following in mind:

- **Which of the Vehicle unknowns are the highest priority?**
- **What are your ideas on addressing the highest priority Vehicle Management & Operations unknowns?**
- **What should be the areas of greatest focus for each Vehicle pillar in the next 2-3 years?**
- **What are the near-term next steps for each Vehicle pillar early adoption?**
- **Specific questions associated with the concepts within the Vehicle pillars and barriers**

Please think about and populate the conferences I/O tool with your individual thoughts, industry perspectives, and up-vote those concepts you agree with.
Poll

ConOps Familiarity

Polling is anonymous

Please rate your familiarity with the UAM ConOps

https://arc.cnf.io/sessions/akh3/#!/dashboard
Individual Vehicle Management & Operations

Scope and Focus

Safely operate UAM vehicles in and around metropolitan areas while maintaining compliance with all required operational rules and procedures.

Barriers
- Safe Urban Flight Management
- Increasingly Automated Vehicle Operations
- Certification & Ops Approval
- Ground Ops & Maintenance
Individual Vehicle Management and Operations

Barrier: Safe Urban Flight Management

Develop capabilities for safe, efficient, and accommodating flight planning and execution in metropolitan areas, including navigation performance sufficient for medium complexity operations in urban environments, assuring controlled flight for safe contingency management (including cyber attacks), and compliance with regulations other constraints (such as noise limits).

NASA Community ConOps

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- **Advanced vehicle technology** (CNSI, avionics etc.) and information exchange allow for **performance-based operation**

Areas with Remaining Unknowns

| Navigational Performance Requirements | NOTAMs | CNSI Requirements | Off-Nominals & Contingency Operations | Specific Equipage and DAA Technology |
Individual Vehicle Management and Operations

Barrier: Increasingly Autonomous Vehicle Operations

Develop highly automated capabilities and associated operational procedures to enable cost-effective scalability by increasing the ratio of vehicle operations to human operators and support staff.

NASA Community ConOps

- **Highly automated vehicles** capable of performing most operations with minimal human interaction

- **Increasingly automated capabilities** of vehicles reduce cost for flight crew training and vehicle operations while maintaining an equivalent level of safety

- **Advanced automation** compared to what is currently available will enable the vehicle to identify the lowest risk emergency landing alternative.

Areas with Remaining Unknowns

- DAA Technology
- Certification of Automated Systems
- Training for Flight Crew & Operator
- Human Interaction Roles & Responsibilities
Develop a framework and corresponding methods of compliance for the holistic certification of advanced automation, humans, and operations of a UAM aircraft, as well as regulations and approval processes for commercial urban operations.

**NASA Community ConOps**

- Certification likely occurs under the existing framework regulations (14 C.F.R. 121, 135, et al.)

- Advanced methods to test and certify high-levels of automation approaching Artificial Intelligence will likely be developed.

- Certificated Maintenance processes have been developed to ensure vehicles are properly maintained.

- Flight Crew and maintenance professional training will include a curriculum that covers areas unique to UAM.

- The flight crew will have sufficient training to meet their allocated requirement of identifying possible maintenance actions.

**Areas with Remaining Unknowns**

- Certification of Vehicle
- Certification of Flight Crew
- Certification of Operator
- Certification of Maintenance Facilities & Personnel
- Certification of Parts & Supply Chain
Develop guidance and requirements to ensure safe and efficient maintenance and routine vehicle handling between flights, including considerations for Vertiport design and operations.

**NASA Community ConOps**

- **Ground operations at the vertiport will be the responsibility of the vertiport operator** who may contract with vehicle operators and ground services to provide routine vehicle maintenance at the vertiport, and maintenance, repair, and overhaul (MRO) providers.

- **Ground operations include an efficient way to recharge/refuel aircraft** in a manner that ensures safe operation and ensures the safety of flight crew, ground crew, and passengers.
  - May include an automated or flight crew safety briefing
  - Passengers are guided safely through the vertiport environment and around safety hazards

- **MRO facilities will provide both minor and major maintenance** supplied by secure certificated supply chains.
  - The types of services provided at vertiports may be constrained by the location of the vertiport and the level of traffic at the vertiport

**Areas with Remaining Unknowns**

- Ground Services Training
- Minimum Level of Maintenance Needed at Vertiports
- Supply Chain Certification
- Non-Maintenance Services at Vertiports
### Individual Vehicle Management & Operations

<table>
<thead>
<tr>
<th>Unknowns</th>
<th>Key Issues for Further Exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-Nominals &amp; Contingency Operations</td>
<td>How will off-nominal situations be managed and what is the role of the flight crew? How does this differ if there is no crewmember onboard the vehicle?</td>
</tr>
<tr>
<td>Human Interaction Roles &amp; Responsibilities</td>
<td>What is the flight crew capability? How is automation envisioned to enable this? Does it rely on there being someone onboard the vehicle?</td>
</tr>
<tr>
<td>Certification</td>
<td>How will vehicles, operators, flight crews, supply chains, and maintenance professionals/facilities be certified? Can occur using the existing framework or are new regulations needed? How will automation be certified?</td>
</tr>
<tr>
<td>Training</td>
<td>What amount of flight hours and educational training requirements will there be for flight crews, operators, and maintenance professionals? How does the training compare to that of a traditional pilot? How does it differ?</td>
</tr>
<tr>
<td>Supply Chain Certification</td>
<td>How can the integrity of the supply chain be ensured?</td>
</tr>
<tr>
<td>DAA Technology</td>
<td>What are the key outstanding research questions that remain for detect and avoid? What will be the requirements for these systems in the UAM context?</td>
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</tbody>
</table>
Poll
Vehicle Management/Ops Unknowns
Polling is anonymous

Which of the Individual Vehicle Management & Operations unknowns are the highest priority?
https://arc.cnf.io/sessions/akh3/#!/dashboard
Poll

Addressing the Unknowns

Polling is anonymous

What are your ideas on addressing the highest priority Vehicle Management & Operations unknowns?

https://arc.cnf.io/sessions/akh3/#!/dashboard
Poll
Near-Term Needs

Polling is anonymous

What should be the areas of greatest focus for UAM Individual Vehicle Management & Operations in the next 2-3 years?

https://arc.cnf.io/sessions/akh3/#!/dashboard
Poll

Early Adoption

Polling is anonymous

What are the near-term next steps for Individual Vehicle Management & Operations early adoption?

https://arc.cnf.io/sessions/akh3/#!/dashboard
QUESTIONS

Use Conferences I/O

https://arc.cnf.io/sessions/xsa9/#!/dashboard

Image Source: NASA UAM Grand Challenge Industry Day
Design, certify and produce airworthy, mission-capable, integrated vehicles that operate safely in all weather conditions required by the mission, with adequate passenger comfort and sufficiently low levels of noise.

Barriers

- Vehicle Design & Integration
- Airworthiness Standards & Certification
- Vehicle Noise
- Weather-Tolerant Vehicles
- Cabin Acceptability
- Manufacturing & Supply Chain
Develop “mission-capable,” integrated vehicles with automated flight critical systems that are compatible with Vertiports and meet all required attributes simultaneously to be safe; operationally and economically competitive with competing transportation modes; environmentally responsible; and secure from digital attack.

**Electric propulsion systems and lightweight structures** enable vehicle configurations tailored to UAM missions, with lower manufacturing and operational cost and lower noise signatures (compared to vehicles in the 2010s).

**Fly-by-wire control systems** enable new smaller UAM vehicle configurations to take advantage of electric propulsion.

**Current vehicle fuel reserve requirements will be modified** to account for the short distance of UAM flights.

**High-speed computing** and **advanced automation** accelerate development cycles to efficiently bring promising concepts to market.

**Vehicle design** eliminate electromagnetic interference (EMI)/radio frequency interference (RFI) between onboard systems, offboard systems, and other radio frequency-emitting devices in urban areas.

**Areas with Remaining Unknowns**

- Resiliency to EMI/RFI
- New Testing and Verification Approaches
- Fuel Reserve Requirements
Develop a means of initially certifying and allowing for continuing certification of novel and/or rapidly evolving vehicles in a cost- and time-effective manner, including developing certification requirements and means of compliance for vehicles and propulsion systems as well as ensuring harmonious international regulations and standards.

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- **Enhance existing regulatory framework**, where appropriate, for the certification of UAM vehicles.
- Some **certification requirements may be updated**. For example, rather than freeze the configuration, there may be ways for the process to be more adaptable so that manufacturers can **certify as they build**.
- Standards for UAM vehicles incorporate **unique elements of UAM operations** such as automation/artificial intelligence, distributed electric propulsion, and interoperability with the U4-UOE.
- Approaches for **vehicle and component certification** for UAM will keep pace with **accelerating technology development**.
- **Surveillance** standards, standards for detect-and-avoid, and maintenance/inspection standards will be developed.
- New testing and certification standards and are **harmonized internationally** so that flight operations are not cost-prohibitive.

Areas with Remaining Unknowns

- Standards for New Technology
- Certification of Automation
- DAA Standards
Develop vehicle designs and technologies to reduce vehicle noise during all phases of flight; including taxi, take-off/departure, approach/landing, and cruise.

- Vehicles designed to meet noise levels that are acceptable to the communities in which they operate.
- Noise level only slightly above the level of ambient noise.
- Vehicle noise reduced through advanced design and incorporation of noise reduction technologies enables quiet vehicle operations including distributed electric propulsion and low-noise rotors.
- Community noise measured in the context of a fleet in addition to measuring noise from a single vehicle.
- Noise standards at UML-4 are reduced compared to UMLs 1 through 3 and will continue to evolve.

Areas with Remaining Unknowns

Noise Standards
Vehicle Development & Production

Barrier: Weather-Tolerant Vehicles

Develop vehicles that are capable of safely flying into and maintaining control in poor, yet frequently experienced, weather conditions, including moderately high winds, low visibility, and high density altitudes.

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• UAM vehicles operate safely in weather and climate conditions experienced in the urban environment, such as turbulence due to thermal heating/cooling or wind shear due to obstacles.

• Designed for the characteristics of the local markets in which they operate, such as Denver’s altitude, Phoenix’s temperature, and Chicago’s wind.

• Vehicles designed with performance consummate with the weather expected in the location in which they operate.

Areas with Remaining Unknowns

Weather Monitoring
Vehicle Development & Production

Barrier: Cabin Acceptability

Develop vehicles that provide an acceptable level of passenger comfort and payload protection including ride quality, cabin noise, interior climate control, and vibrations.

NASA Community ConOps

- Cabins **safe for passengers and cargo** in both **nominal and off-nominal** events.
- **Seat belts** that are effective and simple to use and **ergonomically designed spaces** reduce injuries in an accident.
- **Crashworthiness principles** and safety technologies such as **energy absorbing seats** support occupant survivability in crash landings.
- Cabin design will **minimize vibration and noise during turbulence, provide climate control, and assure passenger safety and comfort**.
- Cabins designed so that necessary maneuvers **do not provide significant adverse impact to passenger comfort**.
- Use of **consumer research** and testing will promote strong understanding of **metrics for passenger acceptance**.
- Factors considered in cabin design include **ambient noise, illumination, vibration, temperature**, and **seating configuration**.
- Safe and efficient access to the cabin provided for passengers – including **children and persons with disabilities**.
- Support for **communication between passengers** by active or passive noise cancellation, personal mobile phones for convenience.

Areas with Remaining Unknowns

| Minimum Cabin Design Requirements | Metrics for Cabin Acceptability | Cabin Monitoring |

31
Vehicle Development & Production

Barrier: Manufacturing & Supply Chain

Develop safe, certifiable, high-volume, affordable, secure and rapid manufacturing capabilities as well as a supporting supply chain ecosystem that is robust and scalable.

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- Use of advanced manufacturing techniques combine practices and processes developed across the automotive, aerospace, and other industries.
- Manufacturing processes supported by integrated design, modular configurations, and advanced materials, and new techniques (e.g., 3D printing).
- Supply scaled to the number of vehicles anticipated, flexible vehicle configurations.
- Strict quality and authenticity standards verified by electronic processes for tracking, providence, and authentication of safety-critical components (i.e., block chain, digital authentication) and to protect against cyber and physical security threats.
- Approaches for supply chain qualification keep pace with levels of production for manufacturing high volumes of vehicles.
- Less vertical integration and dependency on single suppliers in supply chains; greater diversity of manufacturers and distributors of parts and materials.
- Close integration between the OEMs, operators, and manufacturers to optimize supply chain management and control costs.

Areas with Remaining Unknowns

- Advanced Manufacturing processes
- Production Rates
- Secure Supply Chain
- Supply Chain Diversity
## Vehicle Development & Production

### Key Issues for Further Exploration

<table>
<thead>
<tr>
<th>Unknowns</th>
<th>Key Issues for Further Exploration</th>
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<tbody>
<tr>
<td>Resiliency to EMI/RFI</td>
<td>How can vehicles be designed to be resilient from EMI/RFI, both of which are prevalent in urban environments?</td>
</tr>
<tr>
<td>Fuel Reserve Requirements</td>
<td>How will fuel requirements be determined for different UAM vehicles</td>
</tr>
<tr>
<td>New Testing &amp; Verification Approaches</td>
<td>Will new testing methods be employed for UAM vehicles or will testing occur using existing methodologies?</td>
</tr>
<tr>
<td>Certification</td>
<td>Will there be UAM-specific regulation for certification or will certification occur within the existing framework?</td>
</tr>
<tr>
<td>Noise Standards</td>
<td>How will noise standards be determined? Will these standards be stricter than they are for traditional manned aircraft? Will local communities have a role (or be consulted) in determining noise standards?</td>
</tr>
<tr>
<td>Weather Monitoring</td>
<td>Will vehicles be designed to include weather sensors? Will weather sensors be mandatory? What type(s)?</td>
</tr>
<tr>
<td>Metrics for Cabin Acceptability</td>
<td>What metrics or factors will be used to determine cabin acceptability? Will cabin acceptability differ for passengers on UAM vehicles than for passengers flying on traditional commercial aircraft?</td>
</tr>
<tr>
<td>Secure Supply Chain</td>
<td>What are the security risks associated with vehicle production? How will parts be authenticated?</td>
</tr>
</tbody>
</table>
Poll
Vehicle Development/Production Unknowns

Polling is anonymous

Which of the Vehicle Development & Production unknowns are the highest priority?

https://arc.cnf.io/sessions/akh3#!/dashboard
Poll

Addressing the Unknowns

Polling is anonymous

What are your ideas on addressing the highest priority Vehicle Development & Production unknowns?

https://arc.cnf.io/sessions/akh3/#!/dashboard
Poll

Near-Term Needs

Polling is anonymous

What are the areas of greatest focus for UAM Vehicle Development & Production in the next 2-3 years?

https://arc.cnf.io/sessions/akh3/#!/dashboard
Poll

Early Adoption

Polling is anonymous

What are the near-term next steps for Vehicle Development & Production early adoption?

https://arc.cnf.io/sessions/akh3/#!/dashboard

Image Source: NASA UAM Grand Challenge Industry Day
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.

<table>
<thead>
<tr>
<th>Baseline ConOps Release</th>
<th>AAM Ecosystem Working Groups</th>
<th>UAM Concept Maturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The UAM Community ConOps Version 1.0 release is targeted for July of 2020</td>
<td>• Each AEWG will address domain specific UAM concepts</td>
<td>• UAM concepts will mature as government, academia, industry, &amp; community coalesce</td>
</tr>
<tr>
<td>• This document will be released into the public domain and serve as the “Vision” ConOps for UAM at UML-4</td>
<td>• The AEWGs will serve as the main forum for concept discussion, feedback, and forward work</td>
<td>• As various UAM activities are realized, such as research &amp; test, the UAM concepts will be updated</td>
</tr>
</tbody>
</table>
For the Vehicle technologies, what year will UML-4 be realized

https://arc.cnf.io/sessions/akh3/#/dashboard
Poll

Future Sessions - Format

Polling is anonymous

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

https://arc.cnf.io/sessions/akh3/#!/dashboard
QUESTIONS
THANK YOU

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