The AAM National Campaigns (NC)

Goal
Ensure AAM safety and accelerate scalability through integrated demonstrations of candidate operational concepts and scenarios

Objectives
1. Accelerate Certification and Approval
2. Develop Flight Procedure Guidelines
3. Evaluate the CNS Trade-Space
4. Demonstrate an Airspace Operations Management (AOM) Architecture
5. Characterize Community Concerns

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# UAM Maturity Levels (UML)

<table>
<thead>
<tr>
<th>UML</th>
<th>Maturity State</th>
<th>UAM Framework and Barriers</th>
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<tbody>
<tr>
<td>UML-1</td>
<td>Initial State</td>
<td><strong>Late-Stage Certification Testing and Operational Demonstrations in Limited Environments</strong>&lt;br&gt;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</td>
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<td>UML-2</td>
<td>Intermediate State</td>
<td><strong>Low Density and Complexity Commercial Operations with Assistive Automation</strong>&lt;br&gt;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 corridors supporting self-managed operations through controlled airspace</td>
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<td>UML-3</td>
<td>Intermediate State</td>
<td><strong>Low Density, Medium Complexity Operations with Comprehensive Safety Assurance Automation</strong>&lt;br&gt;Operations into urban core; operational validation of airspace, UTM inspired ATM, CNS, C^2, and automation for scalable, weather-tolerant operations; closely space UAM pads, ports; noise compatible with urban soundscape; model-local regulations</td>
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<td>UML-4</td>
<td>Intermediate State</td>
<td><strong>Medium Density and Complexity Operations with Collaborative and Responsible Automated Systems</strong>&lt;br&gt;100s of simultaneous operations; expanded networks including high-capacity UAM ports; many UTM inspired ATM services available, simplified vehicle operations for credit; low-visibility operations</td>
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<td>UML-5</td>
<td>Mature State</td>
<td><strong>High Density and Complexity Operations with Highly-Integrated Automated Networks</strong>&lt;br&gt;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</td>
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<td>UML-6</td>
<td>Mature State</td>
<td><strong>Ubiquitous UAM Operations with System-Wide Automated Optimization</strong>&lt;br&gt;10,000s of simultaneous operations (capacity limited by physical infrastructure); ad hoc landing sites; noise compatible with suburban/rural operations; private ownership &amp; operation models enabled; societal expectation</td>
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Unlocking UML-4 helps enable other UAM missions.

**UML-1**
No new commercial urban missions enabled.

**UML-2**
Cargo delivery to/from warehouses & distribution centers in non-urban areas. Increased utility & safety of General Aviation.

**UML-3**
Limited inter-city eCTOL networks. Limited "feeder networks" between rural areas to nearest city. Public service missions.

**UML-4**
Wide-scale on-demand, regional air transportation network.

**Urban Missions**

- Initial eVTOL fleet operations from urban vertiports. (e.g., airport transfer, cargo delivery, initial urban air metro); Public service missions (e.g., air ambulance, disaster relief).
- Increasing network of eVTOL operations to smaller vertiports in IMC. Increase in previous missions. (e.g., early on-demand urban air taxi network, wide-scale, distributed small package delivery).

**“Rural” Missions**

- Cargo delivery to/from warehouses & distribution centers in non-urban areas. Increased utility & safety of General Aviation.
- Wide-scale on-demand, regional air transportation network.

**Define Stability, Control and Performance standards that guarantee ability to safely fly**

1. Degree IFR approaches to zero altitude/zero airspeed above the Touchdown Point (TDP)
2. Determine appropriate Controllability standards that allow for confined space operations in Urban environments

‡Enable refers to critical technologies that can be engineered to extend to other missions.
Help catalyze UML 1, 2...

- NC-DT: Developmental Testing
- NC-1: Operational Safety

Reduce risk of industry UML-3&4 timeline...

- NC-2: Complex Operations
- NC-3: High Volume Vertiports
- NC-4: Scaled Demo

Legend:
- Automation Research and Capability Development
- Integration of Automated Systems Flight Testing
- GC Series and Operational Demonstrations

UML "unlocks" based on a range of publicly available industry projections; not a consensus view.
National Campaign Developmental Test

- Readiness for NASA deployment to external range(s) for NC-1
- Readiness to define impactful operationally relevant scenarios for NC-1
- Readiness to collect comprehensive data during NC-1
- Assessment of partner and community readiness to execute NC-1 testing
- Readiness of external ranges to support NC-1
National Campaign Developmental Test Flights

• Refinement of integrated operational scenarios to maximize impact on NC-1
• Dry Run to evaluate scenarios with “UTES” representing the controls of the test and common data set in a known environment (Edwards)
• Supply early empirical data to help FAA determine how the UAM mission can be integrated into the existing NAS
• Determine network delays and vehicle measurement bias error build-up for airspace providers to update calculations for negotiations and redirecting traffic
• Airspace service providers will not be directing the aircraft trajectories

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National Campaign Developmental Test Simulations

Verify participant integration compatibility with NC airspace environment
- Assessment of system connectivity, distributed latencies
- Evaluation of the airspace procedures and information exchanges to/from all stakeholders
- Assessment of format and content ingestion of airspace constraints, air traffic, and system negotiation of airspace rules and procedures

Early check against airspace services required for NC-1 scenarios
- NASA evaluation of scenario virtual components, virtual traffic density, and flight feasibility
- Demonstration of vehicle/airspace system integration in virtual and hardware in the loop environments
- Demonstration of extended UTM airspace capabilities in support of advanced NC-1 scenario requirements;
- Enable participants to prepare/develop required technologies for NC-1

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NASA-FAA Data Elements Workbook

Track Objectives for UAM Implementation

Identify Data Attributes for Procedures

Example: CG to Clear Obstacles – NASA Grand Challenge

Map for Analysis to Characterize & Integrate New Entrants and Ops
Key Areas of Automation Development to Support the NC Series

**PILOT**
1. Aviate
2. Navigate
3. Communicate

**CONTROLLER**
1. Locate
2. Separate
3. Communicate

**TERPSTER**
1. Populate
2. Evaluate
3. Mitigate
Functional Decomposition of Piloting

- **Aviate**
  - A/C Control
    - Stability
    - Structural limits
    - Flightpath Control
    - Stall
    - Etc.
  - Observe
    - Airmanship
      - Rules
  - Contingency Management
    - Tactical
      - Air Traffic
      - Ground
      - Obstacles
      - Birds
    - Onboard failures
    - Weather

- **Navigate**
  - Plan Mission
    - Interpret mission objectives
    - Path finding
    - AI
  - Follow Mission Plan
    - Pilot commands
    - Waypoint following
    - Intelligent routing
  - Coordinate Mission with other Agents
    - Formation flying
    - Interactive re-routing
    - Surveillance/tracking
    - Etc.

- **Communicate**
  - Aircraft Controlling Entity
    - Pilot in control
    - Company operations center
    - Etc.
  - Agents in Near Vicinity
    - Nearby aircraft
    - Launch & recovery operator
    - Others?
  - Airspace Control Authority
    - ATM
    - UTM
    - Etc.

Action in one category can initiate other functional processes.
NC-1 Operational Safety & NC-2 Complex Operations

Building Blocks for the urban environment

Micro-Plex to one airport based on vehicle category
NC-1 Operational Safety & NC-2 Complex Operations

- Resilient air, ground, cloud CNSI
- UAM procedural leg library (TBO, 4D-TBO, Airborne M&S)
- Automated, arrival, approach and departure procedures
- Fail-operational, simplified vehicle controls and management
- DAA – airborne and surface hazards
- Adaptive trajectory planning and full-envelope auto-flight
- Automated contingency planning and execution
Terminal Base Operations Contingencies (Scenario 3)

**Scenario 3:**
UAM Ports and Approaches

- High-density vertiport and pad operations with combination of real and simulated aircraft
- Recovery from localized disruptions (e.g. rejected TO, late arrival)
- Vehicle contingency / emergency arrival and landing
- Wind shift / vertiport configuration change