Multi-Vehicle (m:N) Control

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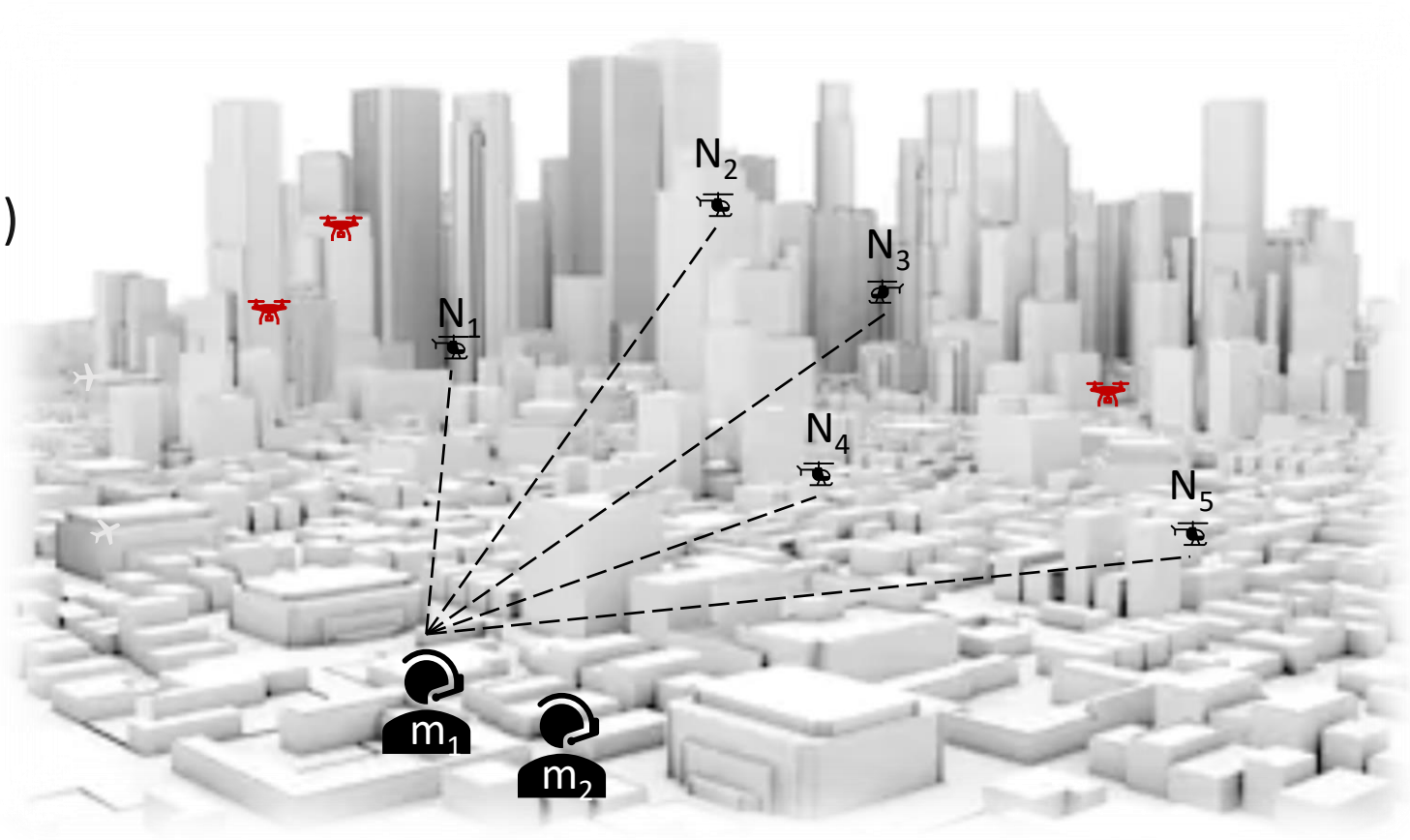
m:N operations

Multi-vehicle control = m:N

- Small group of humans (m) *manages* many highly automated air vehicles (N)
- Not flight vehicle control

Enables desired future state

- Operations scalability
- Increasingly autonomous vehicles

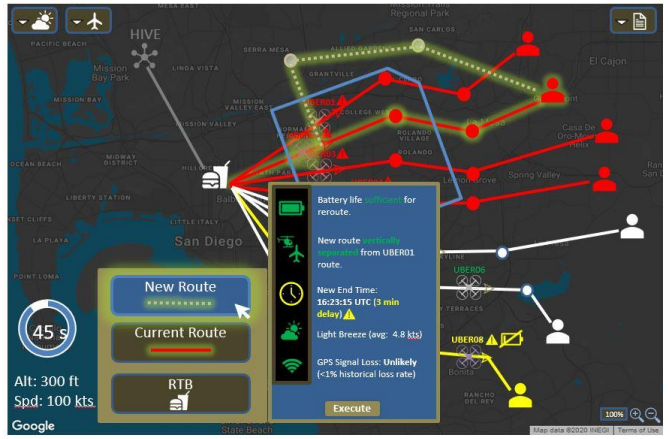


Applicable to range of use cases supporting of advanced air mobility vision

m:N across ARMD

Transformational Tools and Technologies (T^3)

- Progressive human-in-the-loop demos for m:N operation with Joby Aviation
- Foundational human-autonomy teaming research

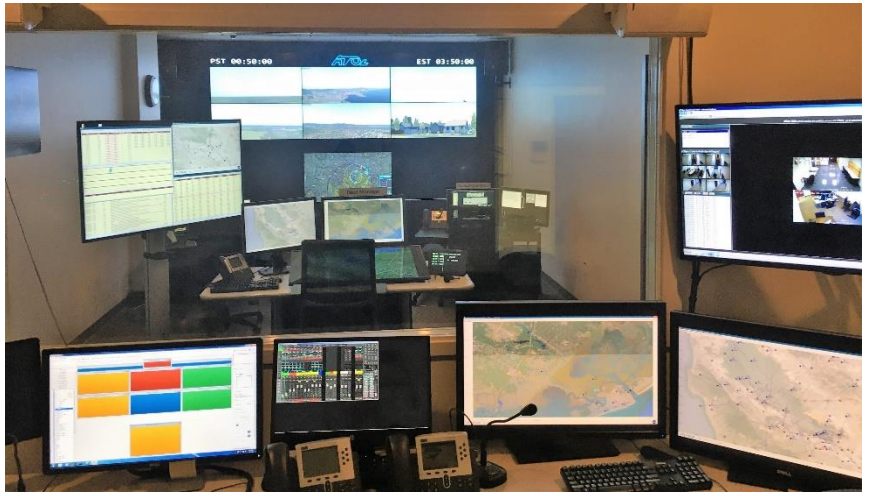


System-Wide Safety (SWS)

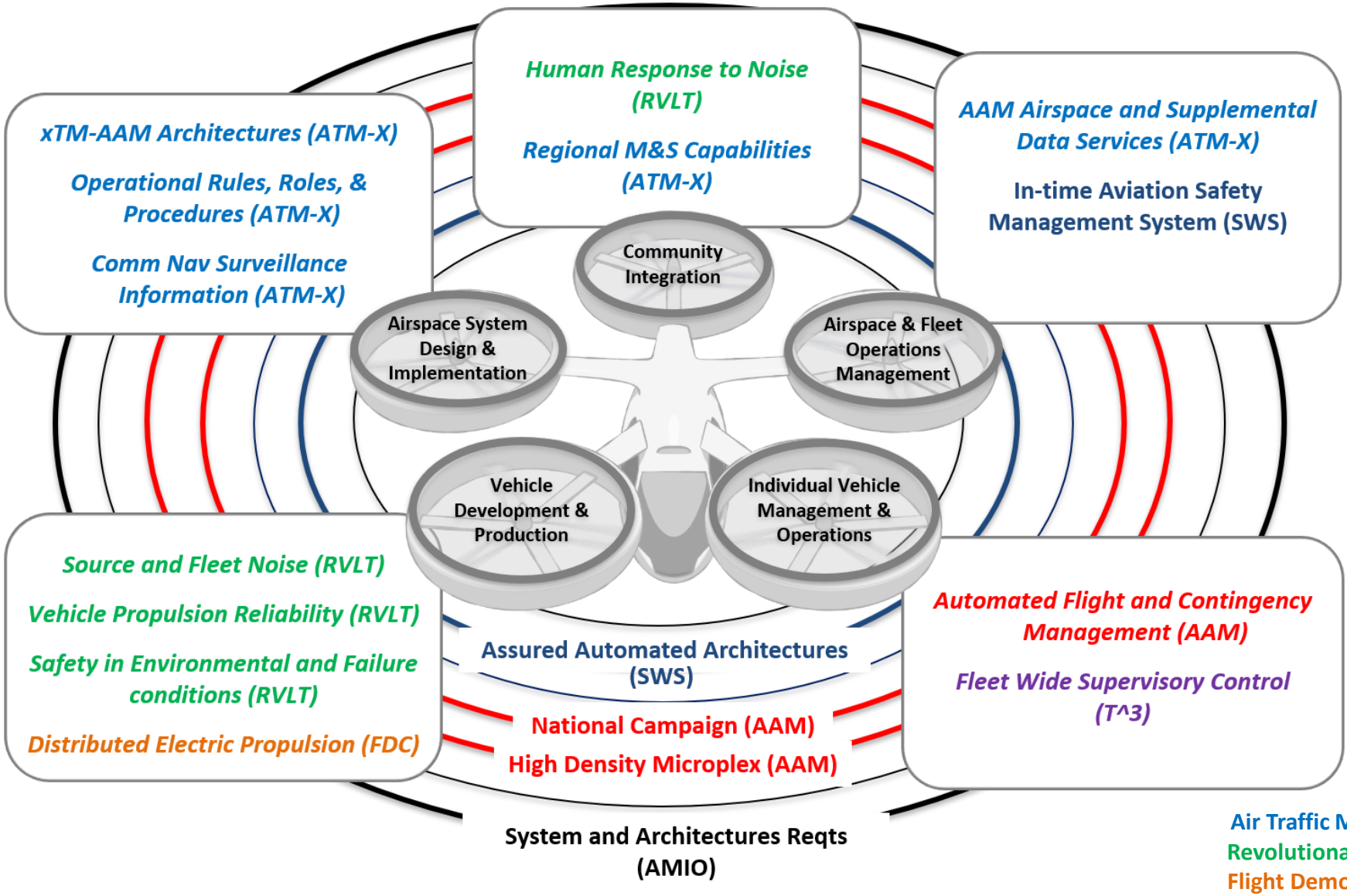
- m:N ConOps development
- Proposed technical challenge includes human-autonomy teaming for wildfire response

Advanced Air Mobility (AAM)

- m:N for high density vertiport operations including ConOps development and BVLOS safety case



m:N across ARMD



Project Legend

Advanced Air Mobility (AAM)
System-Wide Safety (SWS)
Air Traffic Management Exploration (ATM-X)
Revolutionary Vertical Lift Technology (RVLT)
Flight Demonstrations and Capabilities (FDC)
Transformational Tools and Technologies (T^3)
AAM Mission Integration Office (AMIO)

m:N proposed technical challenge

m:N Fleet Management

For efforts through FY26, $6M/year

Enable scalable operations to achieve the full vision and potential of advanced air mobility through development of targeted tools and techniques critical for m:N operation of autonomous fleets

Supporting capabilities

Human-Autonomy Teaming:
Develop tools and techniques to enable a small number of humans (m) to manage many autonomous vehicles (N) across disparate scenarios and dynamic relationships

Autonomous vehicle technology:
Develop a capability description of a UML 4+ autonomous vehicle through characterization of realistic **Intelligent Contingency Management** and **Perception** functions

Exit criteria

- **Demonstration** of m:N operations with a realistically autonomous fleet in 2+ disparate scenarios

- Complementary **artifacts**:
  - Realistic autonomous vehicle characterization
  - Human-autonomy teaming framework
  - Publicly available research tool

m:N in T^3

T^3 Revolutionary Aviation Mobility subproject

- Supports ARMD mission programs by providing a pipeline of solutions and knowledge for **foundational challenges in enabling an advanced air mobility market**

- Enables increasingly autonomous transportation in the **UML-4+ timeframe**

OBJECTIVES

Enable scalable operations to achieve the full vision and potential of AAM through development of targeted tools and techniques critical for m:N operations of autonomous fleets [Draft TC]

Explore and develop airspace management and operations architectures and tools in expectation of increased heterogeneous air traffic

Develop modeling, performance, and control tools & techniques for advanced urban capable aircraft

Explore and demonstrate approaches for scaled vehicle production

Multidisciplinary support

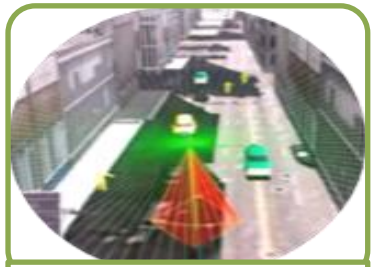
Human Autonomy Teaming

Distribution of roles & responsibilities

Safe, effective teaming strategies

Foundational research tools

Human-in-the-loop simulation



Perception

Vehicle knowledge of surroundings, self, and health through sensing and information processing

Gap analysis and trade studies of capabilities enabling UML 4+

Research-enabling data collection

Intelligent Contingency Management

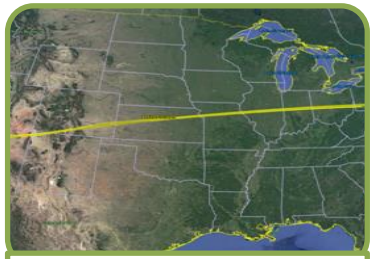
Intelligent machine decisions for unforeseen events with uncertain, incomplete, and unreliable info

Assuring non-deterministic ICM algorithms

Collective Autonomous Mobility

Explore architectures to accommodate heterogeneous autonomous operations in the same airspace

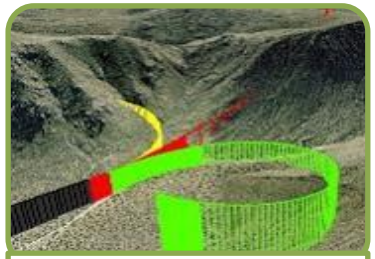
Examine the dynamic relationship among services, operators, and agents



Communication, Navigation, and Surveillance

Autonomous spectrum allocation

Self-optimizing phased array antennas to mitigate interference

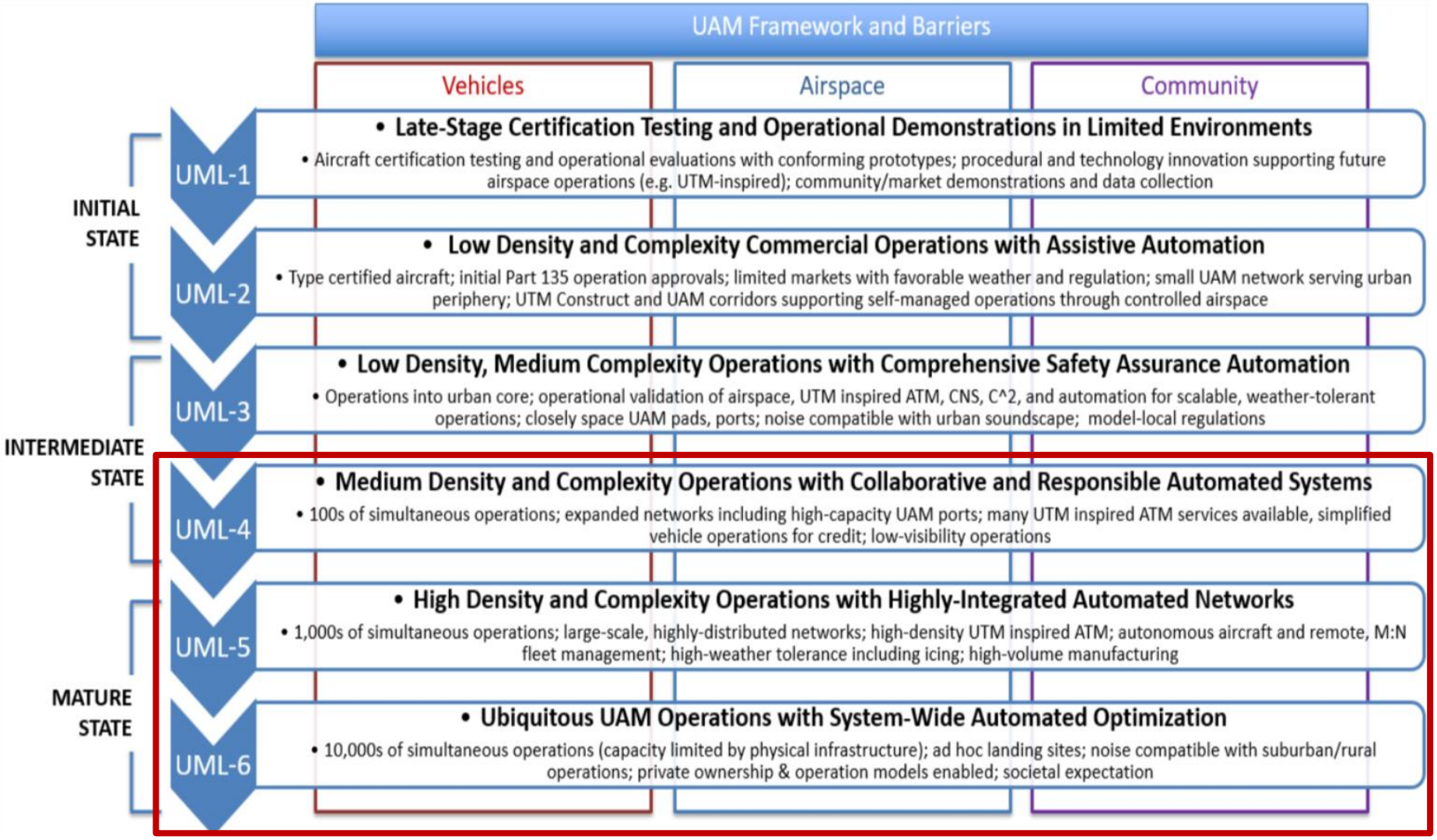


Resilient Autonomy

Inform future certification requirements and strategies for highly autonomous aircraft

Project specific certification plans for general aviation and UAS

m:N in T^3


UAM Framework and Barriers
Vehicles
Airspace
Community
INITIAL STATE
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 corridors supporting self-managed operations through controlled airspace
INTERMEDIATE STATE
UML-3
• Low Density, Medium Complexity Operations with Comprehensive Safety Assurance Automation
• 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
UML-4
• Medium Density and Complexity Operations with Collaborative and Responsible Automated Systems
• 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
MATURE STATE
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

Questions?