



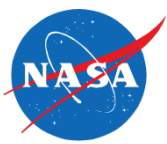
# UAM Coordination and Assessment Team (UCAT) NASA UAM Update for ARTR



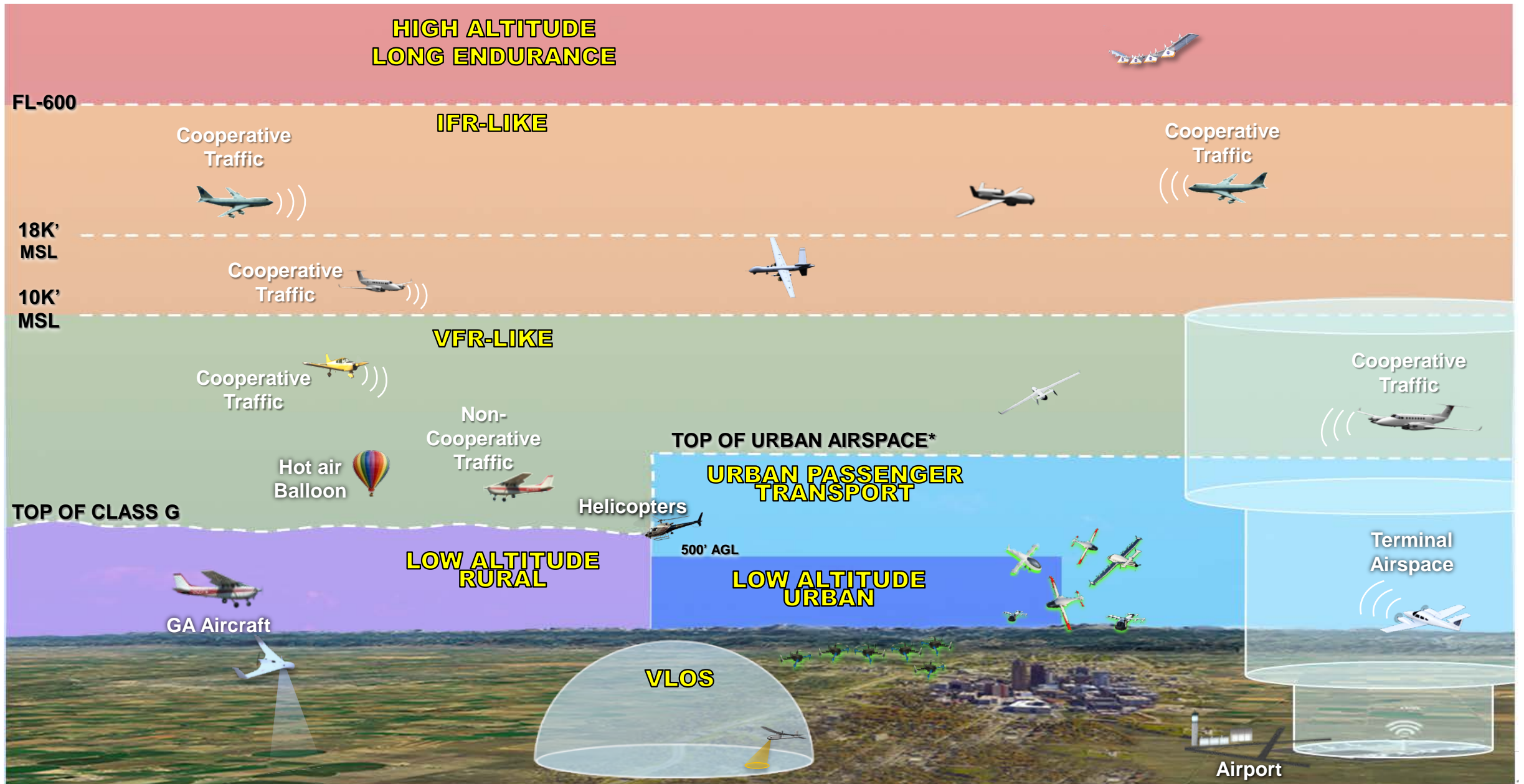
# Overview

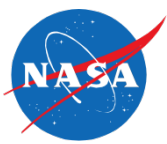
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- UAM Market Studies
- Community-wide Perspectives
- NASA Grand Challenge
- Partnership strategy
- NASA UAM Priorities



# Commercial Operating Environments (OE)





# Urban Air Mobility Market Studies

- ARMD funded two UAM market studies that included
  - Several air taxi/metro models, air ambulance, and last-mile package delivery
  - Considerations for different urban areas, legal and regulatory barriers, & social acceptance issues
- UAM market studies generally found that UAM has economically viable use cases if many challenges are overcome
- Large variability in specific predictions across studies based on differences in assumptions
- Overview of Results:
  - Some assumptions show by ~2028 a highly-automated “air metro” could be profitable and by ~2030 result in ~750M annual passenger trips in 15 metro areas or ~137k pax trips/day/area
  - More conservative assumptions indicate a \$2.5B passenger transport market with ~8.2k pax trips/day/area
  - Air ambulance model may not be profitable, but have high impact on public good
  - By ~2030 “last mile package delivery” could be profitable and result in ~500M deliveries annually





# UAM Passenger Carrying Market Comparisons

## Comparisons of Passengers and Numbers of Vehicles per City

Crown Air Metro	2028	2030
# pax trips/day/city	23,744	136,986
# vehicles/city	273	1,533
# flights/day/city	5,936	34,247
# pax/flight (avg)	4	4

Aggressive on assumptions (i.e. autonomy) and implementation (i.e. vertiport infrastructure)

BAH (baseline)	Near-mid
# pax trips/day/city	8,200
# vehicles/city	410
# flights/day/city	5,500
# pax/flight (avg)	1.49

Fairly conservative assumptions in all except manufacturing volumes, and no predictions for dates

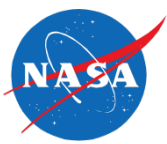
Uber Air Taxi	2025-2030
# pax trips/day/city	60,000
# vehicles/city	400
# flights/day/city	15,000
# pax/flight (avg)	4

Aggressive timeline and assumptions more in-line with Crown market study

## Cost Comparisons Over Time (\$/pax-mile)

Cost (\$/pax-mile)	Launch	"Near-Mid-Term"	"Far-Mid-Term"	"Long Term"
BAH Baseline	N/A	6.25	~2.50	N/A
BAH Low End	N/A	~3.75	~1.50	N/A
Crown	N/A	2.00	1.20	N/A
Uber	5.73	N/A	1.84	0.44

Leverage data to architect a comprehensive approach that defines a realistic progression to open the UAM passenger-carrying market



# UAM Ecosystem Overview

## Industry and Stds Dev Organizations

- Technology Development
- R&D
- Standards
- Summits
- Partnerships
- International

## Federal agencies

- NASA Efforts
- FAA UAM Roundtable
- FAA/OGA initiatives
- DoD

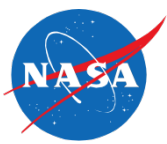
## State and local

- Initiatives
- Smart Cities
- Partnerships
- Academic research

## Community

- Public perception:
- Think tanks and research institutions
- Concern groups





# UAM Ecosystem Needs

- **Holistic Community View.** Realizing the full vision of UAM (specifically for scaled solutions) will be complicated and reliant on a large number of technologies and capabilities maturing simultaneously. The community needs a holistic view of the full ecosystem across diverse capabilities and initiatives.
- **Coordination of Efforts.** The community is large, diverse, and fast-moving. The community would benefit from more effective end-to-end ecosystem coordination that breaks down silos and targets the priority barriers/challenges.
- **R&D Addressing Barriers/Challenges.** Even with all of the participants currently thinking about UAM, there are gaps that aren't being addressed. and that there are barriers/challenges that will require significant time/resources to address
- **Focused Collaboration.** The full benefits from the UAM market won't be opened by enabling a subset of the potential markets. The community would benefit from collaboration that has broad benefits across multiple potential markets.
- **Government Engagement.** Enabling UAM requires Federal, State and Local government support. The community needs effective paths/mechanisms to engage with government across all these levels, and government entities need to engage amongst themselves.



# What's NASA already doing?

- Performed independent Market Studies that have demonstrated the potential of UAM
- Defining an approach with holistic systems point of view, and not simply focusing specific technologies
- Robust planning an execution of Grand Challenge Series that will address barriers/challenges and encourage community collaboration
- Ongoing projects continuing research that significantly contributes to UAM, and pivoting other projects towards a UAM focus
  - UAS Traffic Management (UTM) & UAS Integration in the NAS (UAS-NAS)
  - Flight Demonstrations and Capabilities (FDC), X-57
  - Air Traffic Management - Exploration (ATM-X)
  - System Wide Safety (SWS)
  - Transformative Tools & Technologies (TTT)
  - Revolutionary Vertical Lift Technologies (RVLT)
- New Start Projects with UAM as their top priority
  - Advanced Air Mobility (AAM)
- Leveraging government contacts to help ensure appropriate agency involvement

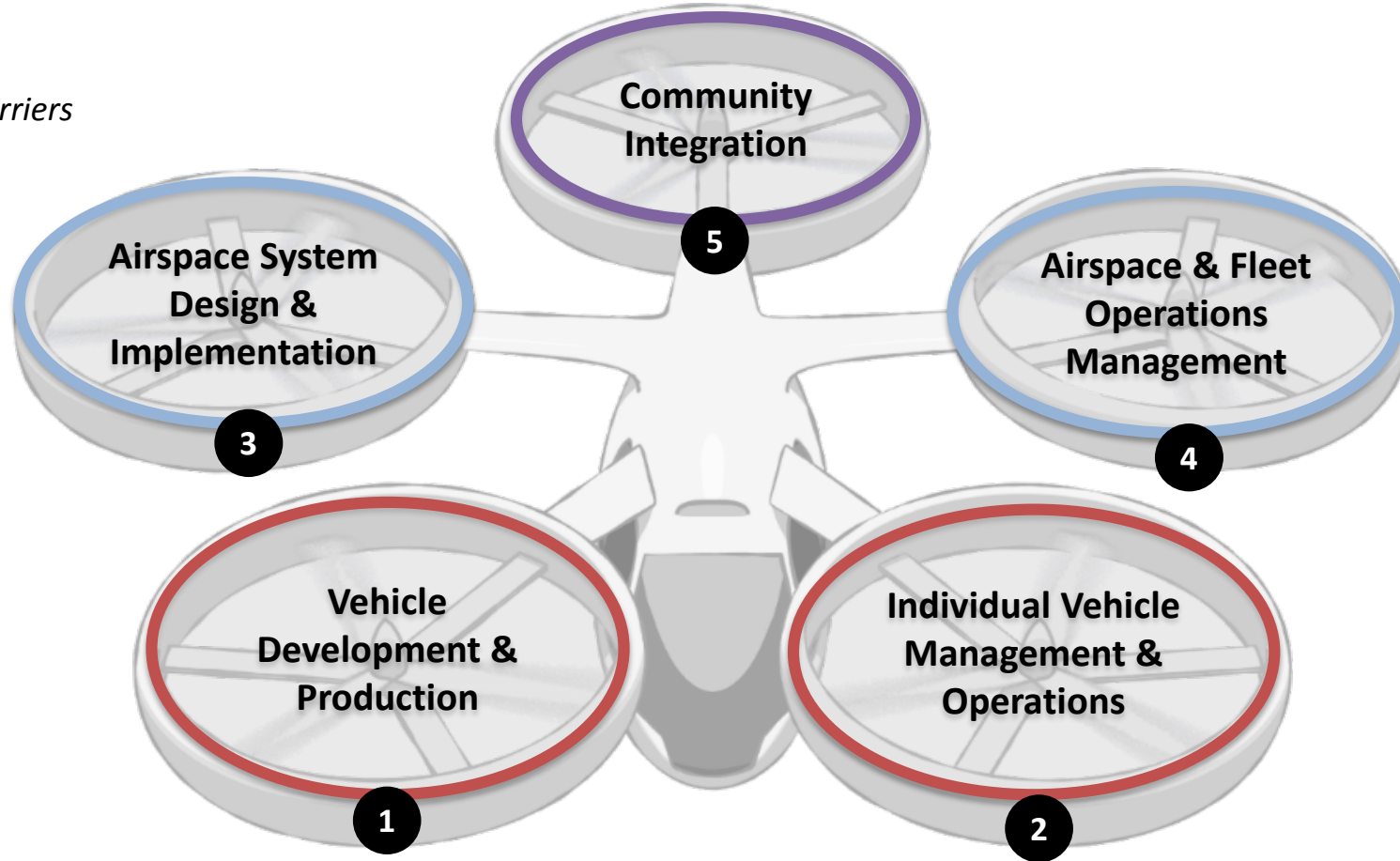
NASA is moving out quickly and intelligently to enable a UAM Ecosystem





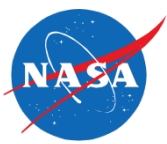
# UAM Vision and Framework

- *Vehicle Barriers*
- *Airspace Barriers*
- *Community Integration Barriers*

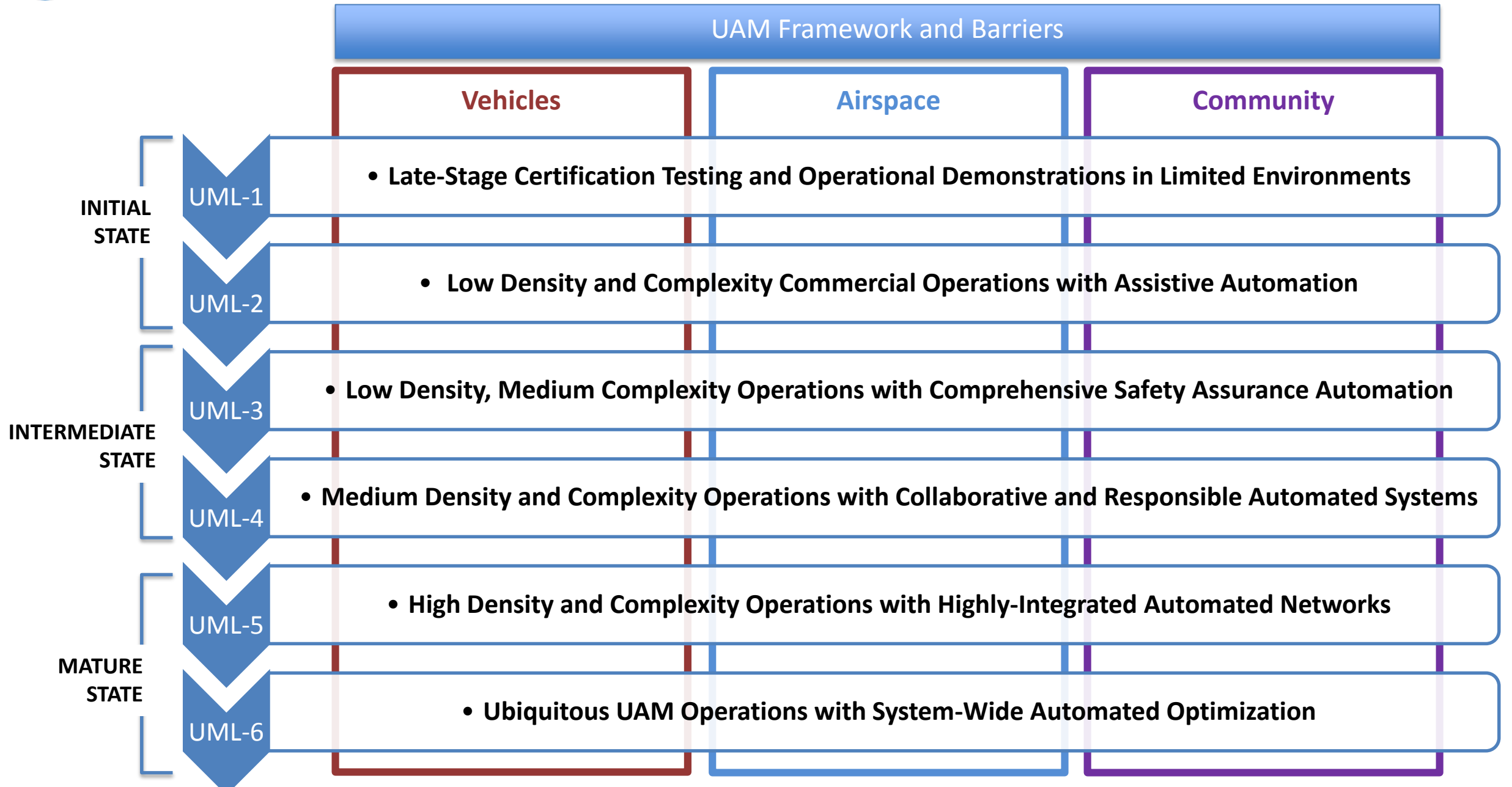


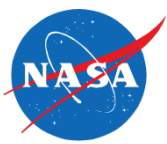
## Urban Air Mobility (UAM) Vision

Revolutionize mobility around metropolitan areas by enabling a safe, efficient, convenient, affordable, and accessible air transportation system for passengers and cargo



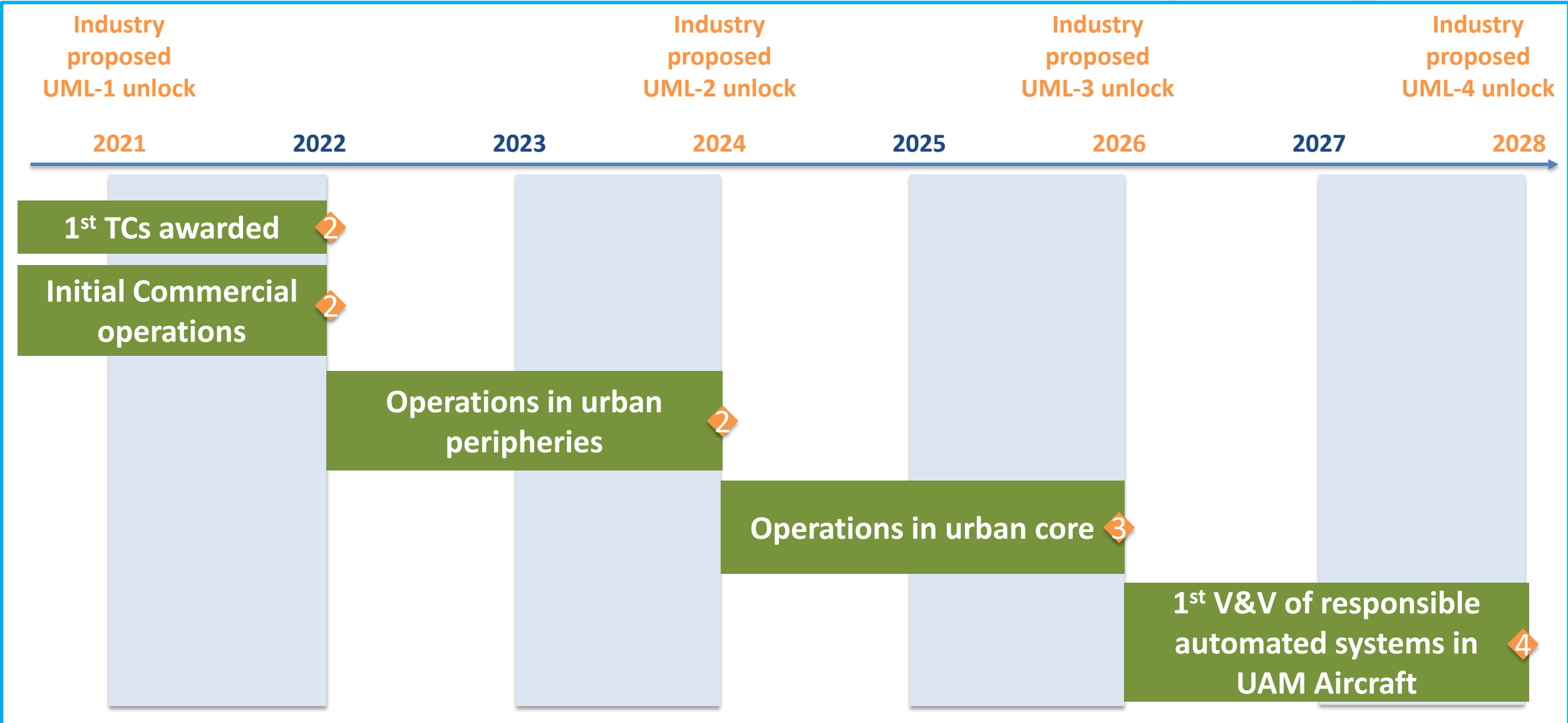
# UAM Maturity Levels (UML)



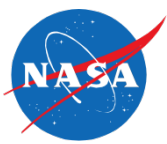


# Representative industry UAM timeline<sup>1</sup> and milestones

# UML-#      ■ Industry milestone



<sup>1</sup> Based on a range of publicly available industry projections; not a consensus view; aggressive



# Preliminary UAM Community Critical Commitment



**Vehicle Development and Operations** Develop concepts and technologies to define requirements and standards addressing key challenges such as safety, affordability, passenger acceptability, noise, automation, etc.

**Airspace Design and Operations** Develop UTM inspired concepts and technologies to define requirements and standards addressing key challenges such as safety, access, scalability, efficiency, predictability, etc.

**Community Integration** Create robust implementation strategies that catalyze public acceptance, local regulation, infrastructure development, insurance and legal frameworks, etc.

## UAM Community Critical Commitment

**Deliver a validated**  
**1) system concept and**  
**2) corresponding set of**  
**requirements**  
**for a safe and scalable UAM**  
**transportation system.**

Achieving a “system of requirements” will require enabling activities such as 1) the UAM Grand Challenge Series, 2) a robust Partnership Strategy, and 3) NASA ARMD Portfolio Execution



# NASA's Approach to Enabling a "Set of Requirements"

## UAM Grand Challenge Series



The UAM GC Series is designed to facilitate technology development, testing, and partnership for critical UAM components

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## UAM Partnership Strategy



The UAM Partnership Strategy is designed to bring the entire UAM ecosystem together in partnership across key challenges and barriers

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## NASA ARMD Portfolio Execution



NASA supports industry via a robust portfolio focused on key challenges validated GC and UAM Partnership Strategy

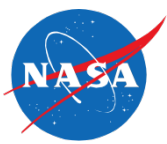
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# The UAM “Grand Challenge” Series

- Challenging the industry to execute ecosystem-wide systems level safety and integration scenarios
- Demonstrate practical & scalable system concepts (i.e. UML-4)
- Builds knowledge base for requirements and standards
- No purse or prize money





# Grand Challenge (GC) Series Overview

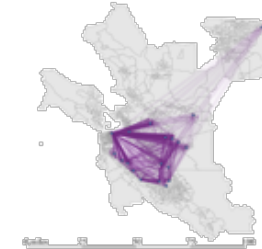
## Vehicles

functional UAM vehicles with threshold level of demonstrated airworthiness



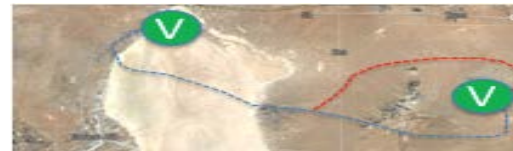
## Airspace Management

airspace and air traffic management technologies and services built and simulated to a threshold level of UAM ATM requirements



## Safety and Integration Scenarios

airworthiness processes and scalable scenarios designed in concert with the FAA, with range(s) and Testbeds as a UAM proving ground

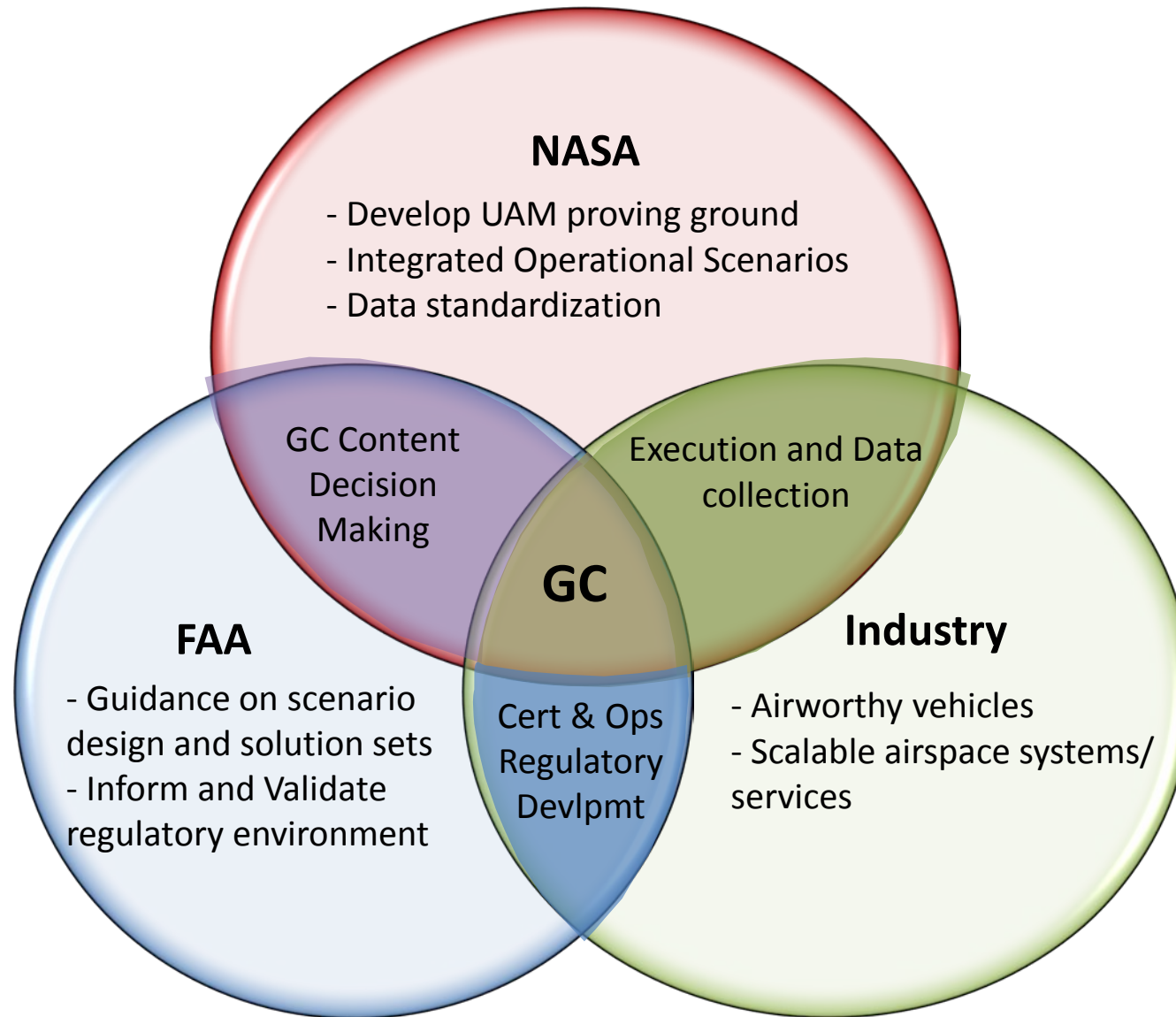


## Stakeholder Integration

societal integration and acceptance of UAM Operations including public acceptance, supporting infrastructure, operational integration, standards organizations, the local regulatory environment, etc.



# NASA/FAA/Industry Relationship for Initial Grand Challenge



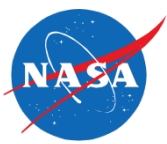




# Grand Challenge Tenets (draft)

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- The GC series will not be a Science Fair
- Don't over-complicate in an attempt to be perfect
  - Corollary: Make GC meaningful for the participants
- NASA is the facilitator and the UAM community is the customer
  - NASA must listen to our customers
  - NASA must ask the question to the community “What will be the most helpful to you?”
  - NASA must synthesize a community response from disparate and conflicting answers to the question above.
- At the end of the GC series we would like for the participants to say, “I got a lot out of being involved in the GC series”



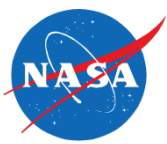
# Initial Grand Challenge Objectives

## Goal

Support requirements and system development for UAM through integrated Demonstrations of vehicle and operational scenarios critical to scalable UAM commercialization

## Objectives

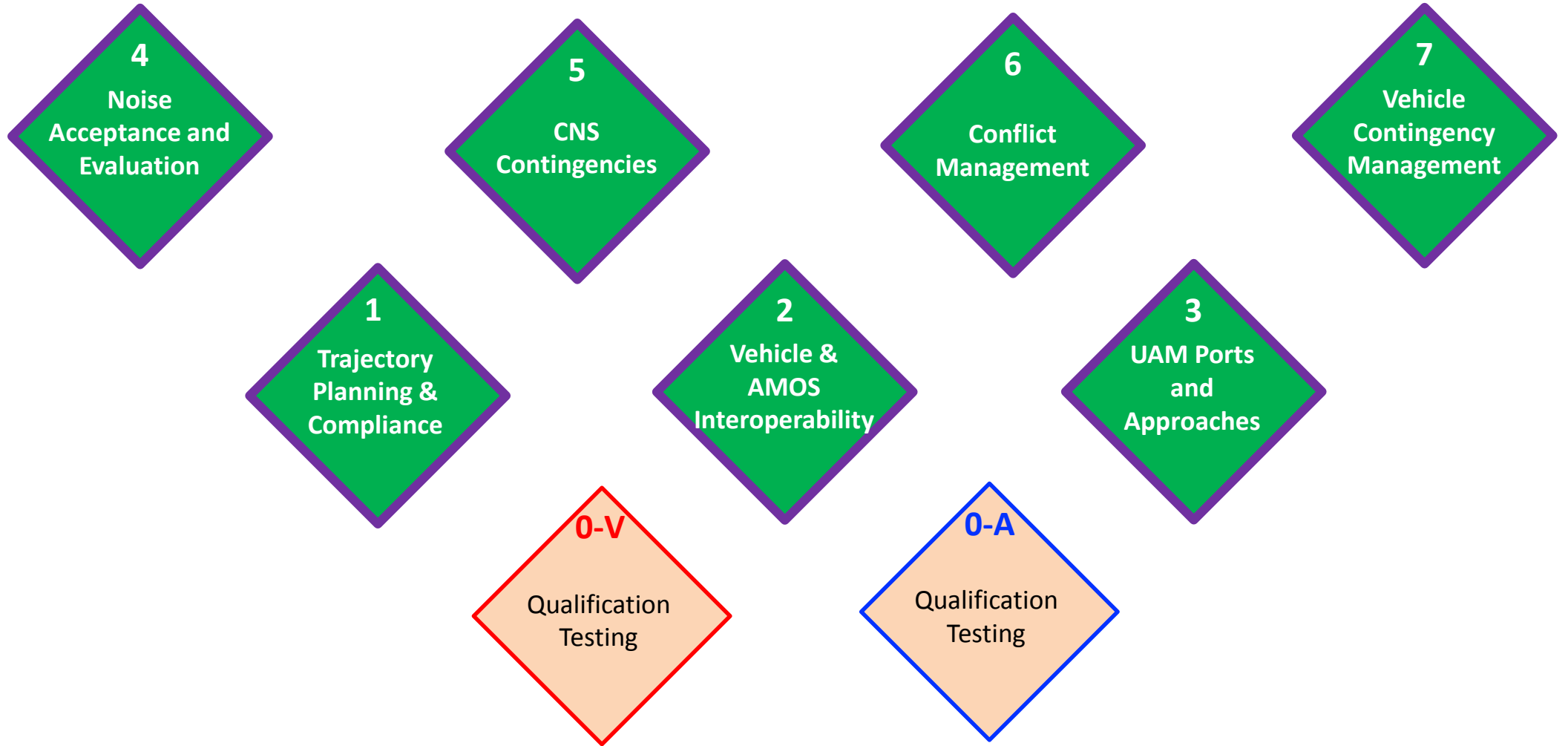
- **Accelerate Certification and Approval.** Develop and assess an integrated approach to vehicle certification and operational approval
- **Develop Flight Procedure Guidelines.** Develop preliminary guidelines for flight procedures and related airspace design criteria
- **Evaluate the CNS Trade-Space.** Explore and evaluate communication, navigation, and surveillance requirements, options, and trade-offs
- **Demonstrate an Airspace Management Architecture.** Demonstrate and document an airspace system architecture, based on the UTM construct, capable of safely managing scalable UAM operations without burdening the current ATM system
- **Develop Autonomy Methods of Compliance.** Create and evaluate standardized flight test scenarios and candidate methods of compliance supporting certification of autonomous flight and airspace systems
- **Characterize Community Considerations.** Conduct initial characterization of passenger and community considerations through vehicle ground noise, cabin noise, and on-board ride quality measurements



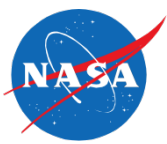
# Proposed Initial GC Scenarios\*

**V** **A** GC Qualification Activities

**■** Proposed Initial GC Integrated System Scenarios



\*Scenario prioritization for Initial GC ongoing with FAA and Industry



# Initial GC Participant Value Proposition

- Opportunity to help shape future UAM Requirements, Regs & Standards – *Decrease potential for negative impacts to stakeholder designs and business cases.*
- Establish the evidence needed to convince regulators that the UAM technologies are safe & mature – *Prevent unnecessary restrictions being placed on UAM market.*
- Demonstrate vehicle systems integrated into airspace – *UTM-construct/3rd party services for scalable, responsive airspace integration*
- Help to educate federal, state and local authorities on UAM societal value & safety – *Achieve public acceptance sooner and reduce potential for push-back.*
- Leverage NASA investment in UAM test ranges and integrated simulation facilities – *Eliminates the need for industry to invest their own resources for these items.*
- Help to build credibility with potential investors and customers – *Secure the necessary capital and user base.*

***By participating in the Initial UAM GC, Vehicle and Airspace Stakeholders have the opportunity to develop solutions that help solve UAM market-enabling challenges.***



# Grand Challenge Series Flow

**Build Up: ~Late 2020**

**Initial Grand Challenge: ~2022**

**GC Series: TBD**

Outcome: Community learning through flight and simulation of critical UAM scenarios in a relevant environment

Outcome: Integrated Demonstrations of vehicle and operational scenarios critical to UAM commercialization

Outcome: Validated requirement sets for scaled operations

**Grand Challenge Build-up: Essential activities to prepare for Initial Grand Challenge**

- Multiple critical activities that build towards Initial GC
- High Priority and focused Integrated/operational scenarios
- Incorporates trade-offs between vehicle and airspace systems
- Challenging to all; not all expected to participate

**Initial Grand Challenge: Learning through real integrated flights**

- Demonstrate integrated capabilities for urban operations
- Define path to commercial operations, solutions oriented

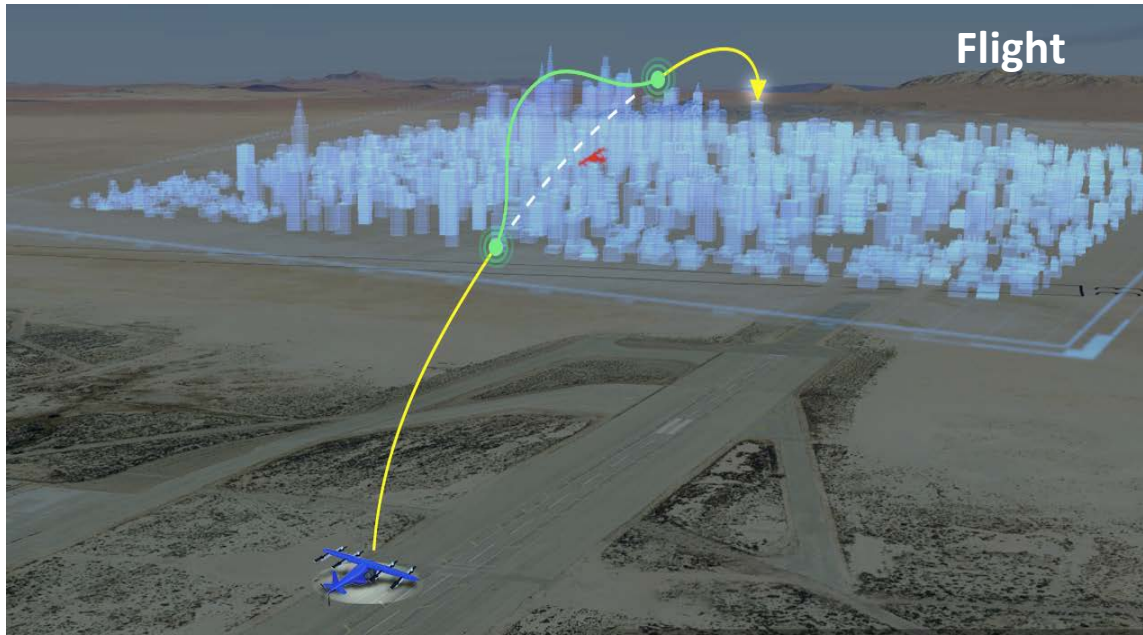
**n**

**Series Culmination**

*Demonstrate scaled operational capabilities in urban environments*



# GC Build-up



## Integrated Vehicle and Airspace Build-up

- Vehicle and airspace systems come together to fly high-priority integration scenarios
- Checkout Initial GC flight scenarios to verify mission and success criteria

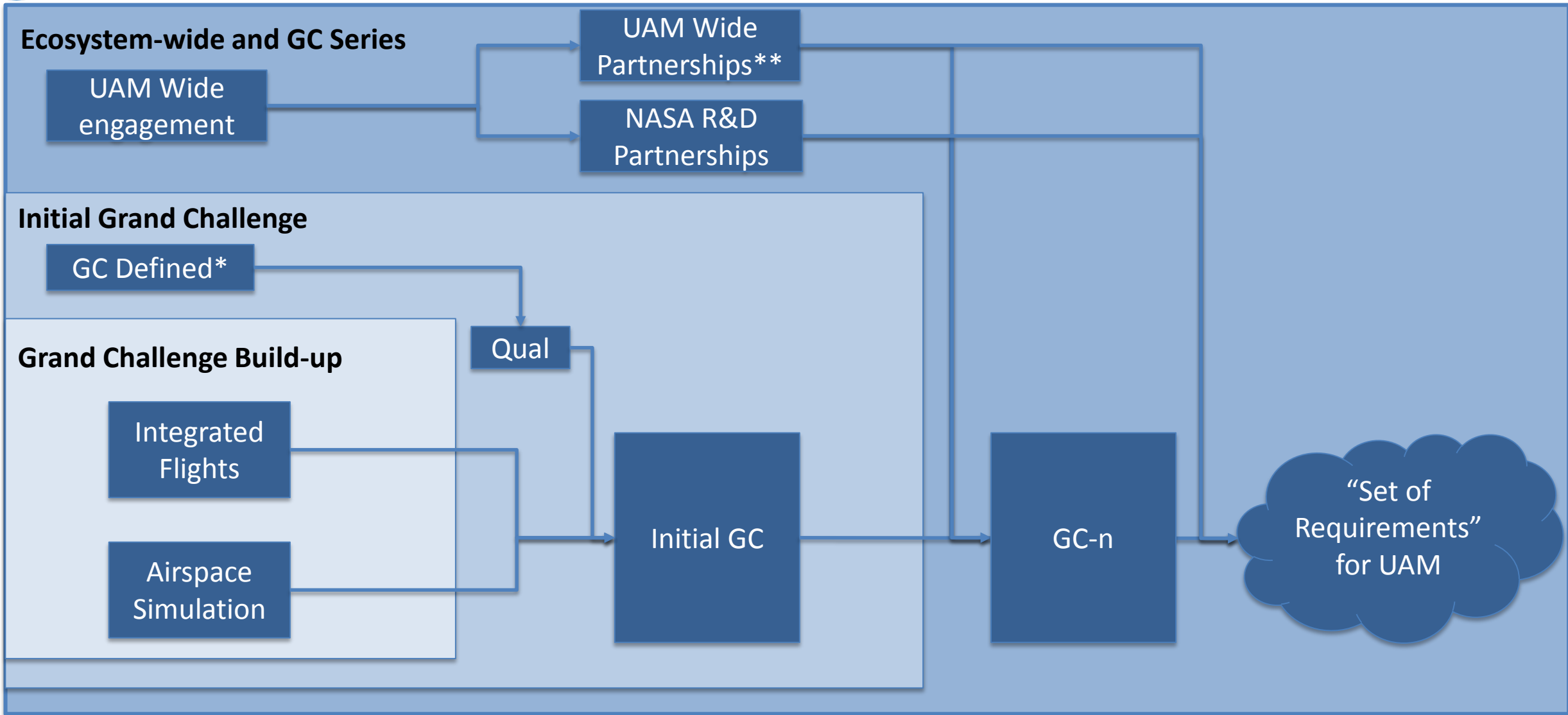
## Interoperability Build-up with Airspace

- Define common interfaces
- Simulations to checkout integrated services before Initial GC
- Checkout of end-to-end services that will eventually demonstrate requirements for scalable UAM ops

**Activities necessary to ensure NASA builds a successful Initial Grand Challenge and provide Industry an opportunity to demonstrate airspace interoperability**



# NASA Proposed UAM Partnership Strategy

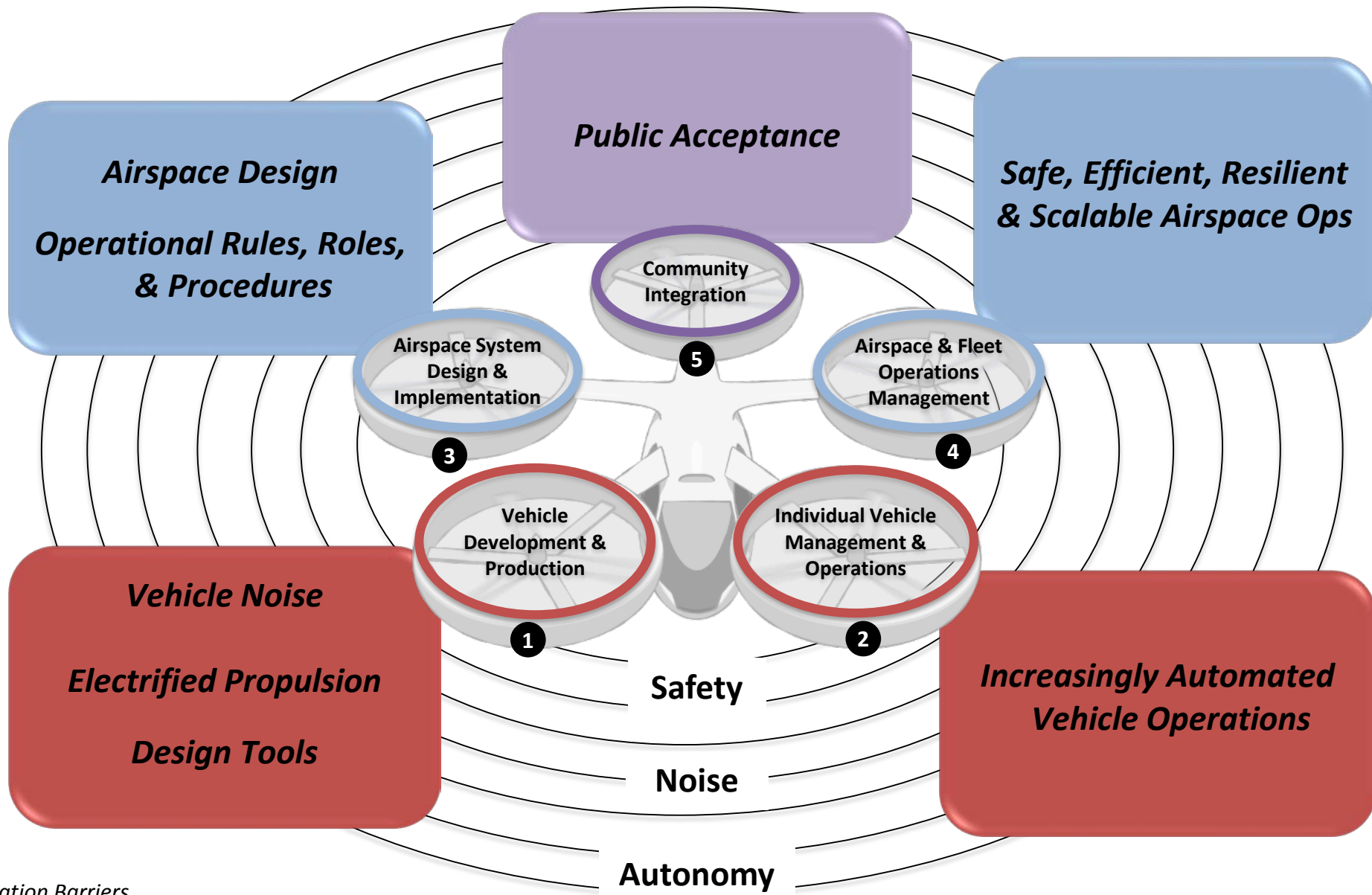


\*Continue to work future GC definition through collaborative partnership workshops

\*\* NASA recognizes it will not be involved in all UAM wide partnership activities



# NASA UAM Priorities



- Vehicle Barriers
- Airspace Barriers
- Community Integration Barriers
- # Pillar number

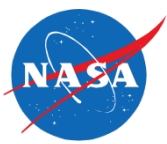




# Summary

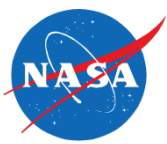
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- NASA believes we understand the needs of the UAM community and we are implementing early efforts to address areas where NASA can have a high impact
- The UAM Grand Challenge is a solutions oriented pathway that requires a critical mass of industry to accelerate UAM
- NASA is robust in our Grand Challenge planning and ready to begin executing
- NASA is implementing a robust research portfolio that we will work in partnership with the industry, and focus on accelerating critical elements of UAM



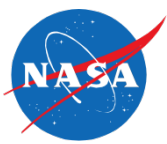
# Acronyms

<b>AAM</b>	Advanced Air Mobility
<b>AC</b>	Aircraft
<b>AIA</b>	Aerospace Industries Association
<b>ARMD</b>	Aeronautics Research Mission Directorate
<b>ARTR</b>	Aeronautics Research and Technology Roundtable
<b>ASTM</b>	ASTM International, formerly known as American Society for Testing and Materials
<b>ATC</b>	Air Traffic Control
<b>ATM</b>	Air Traffic Management
<b>ATM-X</b>	Air Traffic Management-eXploration
<b>C<sup>2</sup></b>	Command and Control
<b>CC</b>	Critical Commitment
<b>Cert</b>	Certification
<b>CNS</b>	Communication, Navigation and Surveillance
<b>CNSI</b>	Communication, Navigation, Surveillance, and Information
<b>Comm</b>	Communication
<b>CONOPS</b>	Concept of Operations
<b>DAC</b>	Drone Advisory Council



# Acronyms

<b>DFW</b>	Dallas/Fort Worth International Airport
<b>DOT</b>	Department of Transportation
<b>eVTOL</b>	Electric Vertical Takeoff and Landing
<b>ExComm</b>	Executive Committee
<b>FAA</b>	Federal Aviation Administration
<b>FDC</b>	Flight Demonstrations and Capabilities
<b>GAMA</b>	General Aviation Manufacturers Association
<b>GC</b>	Grand Challenge
<b>IPP</b>	Integration Pilot Program
<b>LA</b>	Los Angeles
<b>M&amp;S</b>	Modeling and Simulation
<b>MOC</b>	Means of Compliance
<b>NAS</b>	National Airspace System
<b>NASA</b>	National Aeronautics and Space Administration
<b>OAA</b>	Office of Associate Administrator
<b>OEM</b>	Original Equipment Manufacturer
<b>OGA</b>	Other Government Agency



# Acronyms

<b>Ops</b>	Operations
<b>Pax</b>	Passenger
<b>PM</b>	Project Manager
<b>Qual</b>	Qualification
<b>R&amp;D</b>	Research and Development
<b>RFI</b>	Request for Information
<b>RVLT</b>	Revolutionary Vertical Lift Technologies
<b>sUAS</b>	Small Unmanned Aircraft Systems
<b>SWS</b>	System Wide Safety
<b>TBD</b>	To Be Determined
<b>TC</b>	Type Certificate
<b>TRB</b>	Transportation Research Board
<b>UAM</b>	Urban Air Mobility
<b>UAM TM</b>	Urban Air Mobility Traffic Management
<b>UAS</b>	Unmanned Aircraft System
<b>UAST</b>	Unmanned Aircraft Safety Team



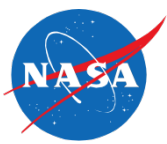
# Acronyms

<b>UCAT</b>	UAM Coordination and Assessment Team
<b>SE</b>	Systems Engineering
<b>SME</b>	Subject Matter Expert
<b>SPMR</b>	Strategic Portfolio Management Review
<b>TTT</b>	Transformative Tools & Technologies
<b>UML</b>	UAM Maturity Level
<b>UPP</b>	UTM Pilot Program
<b>US</b>	United States
<b>UTM</b>	Unmanned Aircraft System Traffic Management
<b>V&amp;V</b>	Verification and Validation



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# BACK-UP



# UAM Ecosystem Status

## Industry and Stds Dev Organizations

- **R&D:** more than 100 vehicle prototypes in development, UAM TM ecosystem
- **Standards:** GAMA, AIA, ASTM, Elec Propulsion
- **Summits:** Uber Elevate, Farnborough UAM conference, Aviation Week UAM series,
- **Partnerships:** Uber Elevate
- **International:** US companies flying to gain experience in pilot cities; Tokyo, Singapore, Dubai, Sao Paolo

## Federal agencies

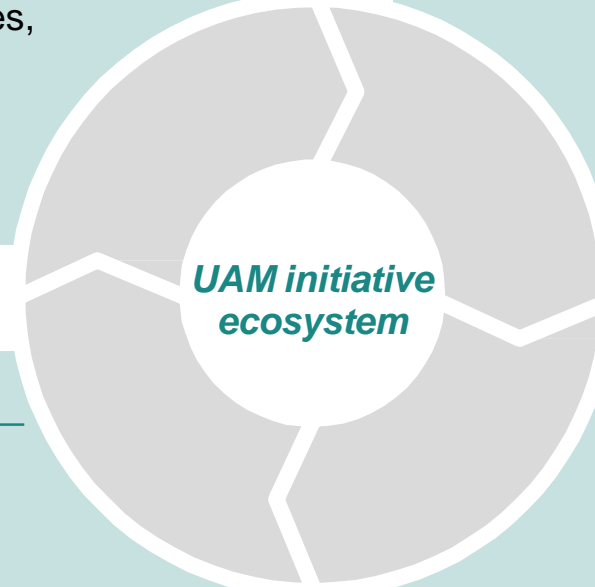
- **NASA Efforts:** Grand Challenge, X-57, UTM, UAS in the NAS, RVLT, Autonomy & Acoustics Workshops, ARTR
- **FAA UAM Roundtable:** industry roundtable, paths to certification (e.g. 21.17b) and operations (e.g part 135),
- **FAA/OGA initiatives:** DAC, UAST, UAS ExComm, IPP, UPP, DOT Autonomy Guidance and TRB

## State and local

- **Initiatives:** State and local interest in initiatives like IPP, UPP, Test Sites, UAM demos
- **Smart Cities:** several local authorities are implementing city-wide initiatives
- **Partnerships:** DFW and Uber, LA Olympics
- **Academic research:** progressive leaders are funding studies to accelerate UAM

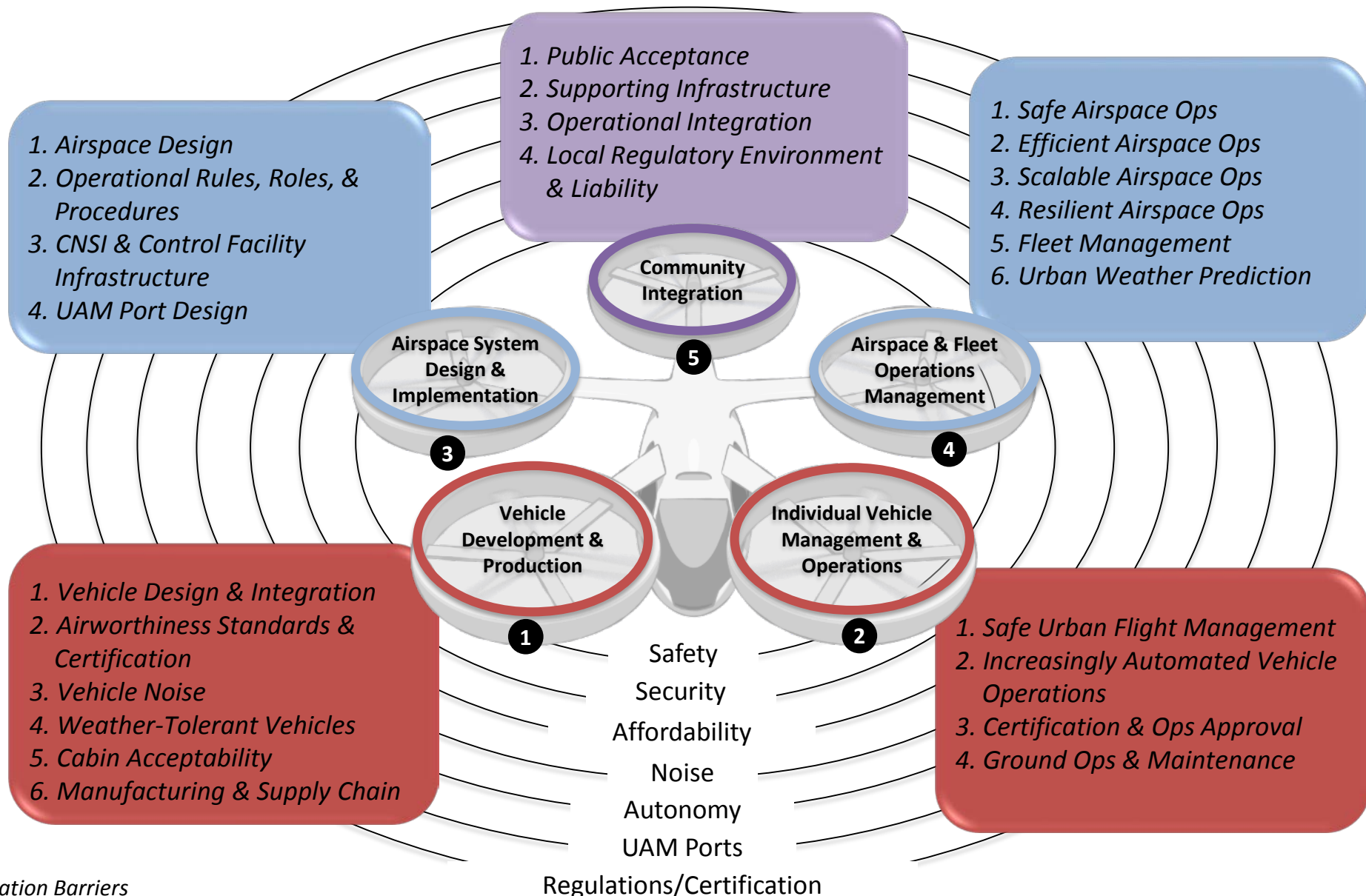
## Community

- **Public perception:** OEMs and others are working to study consumer perception of UAM (e.g., Airbus)
- **Think tanks and research institutions:** Aspen Institute Future of Work
- **Concern groups:** neighborhood noise, environmental, and automation interest groups are beginning to voice interest at UAM forums





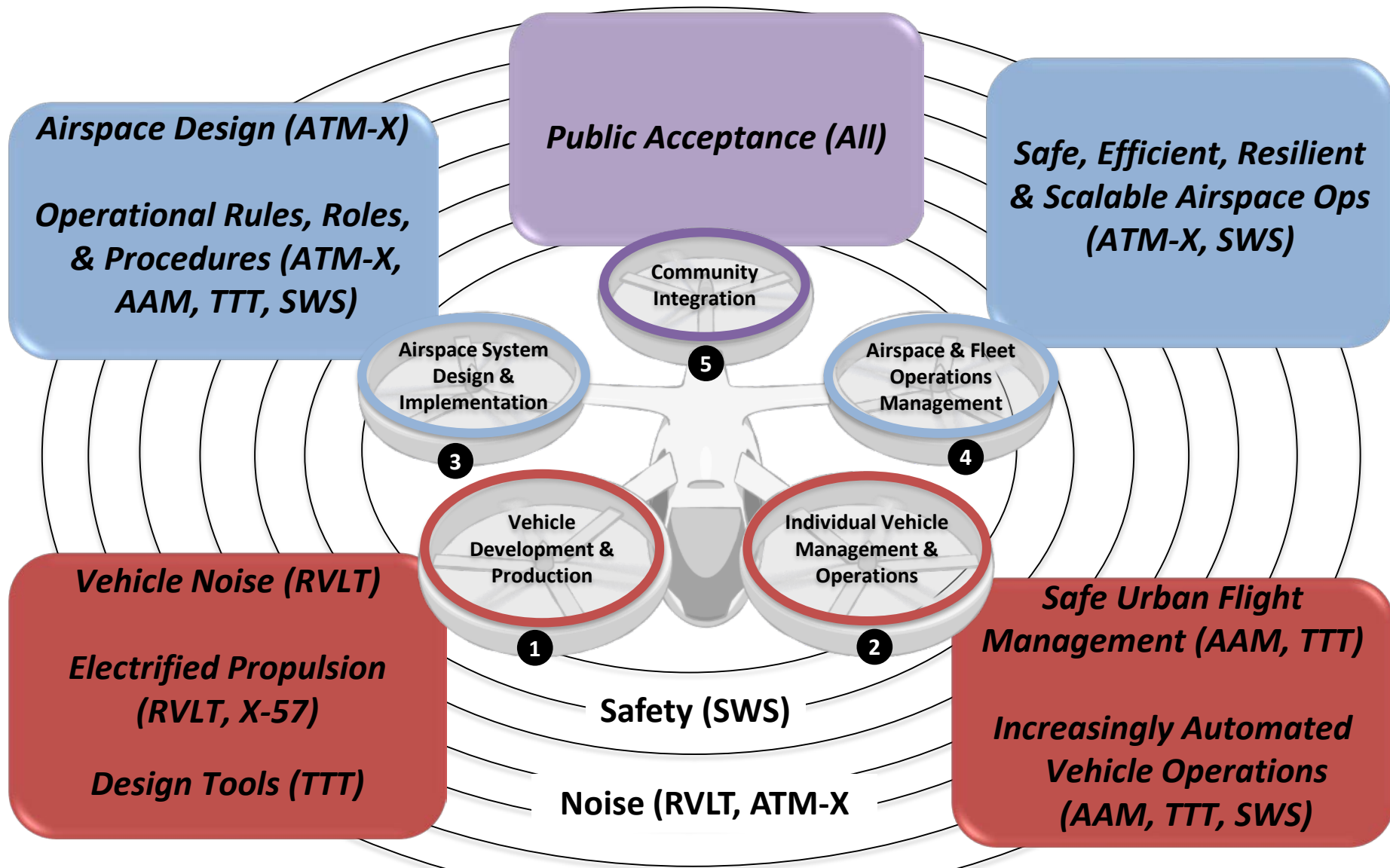
# UAM Framework and Barriers



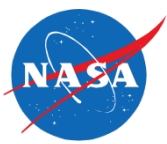




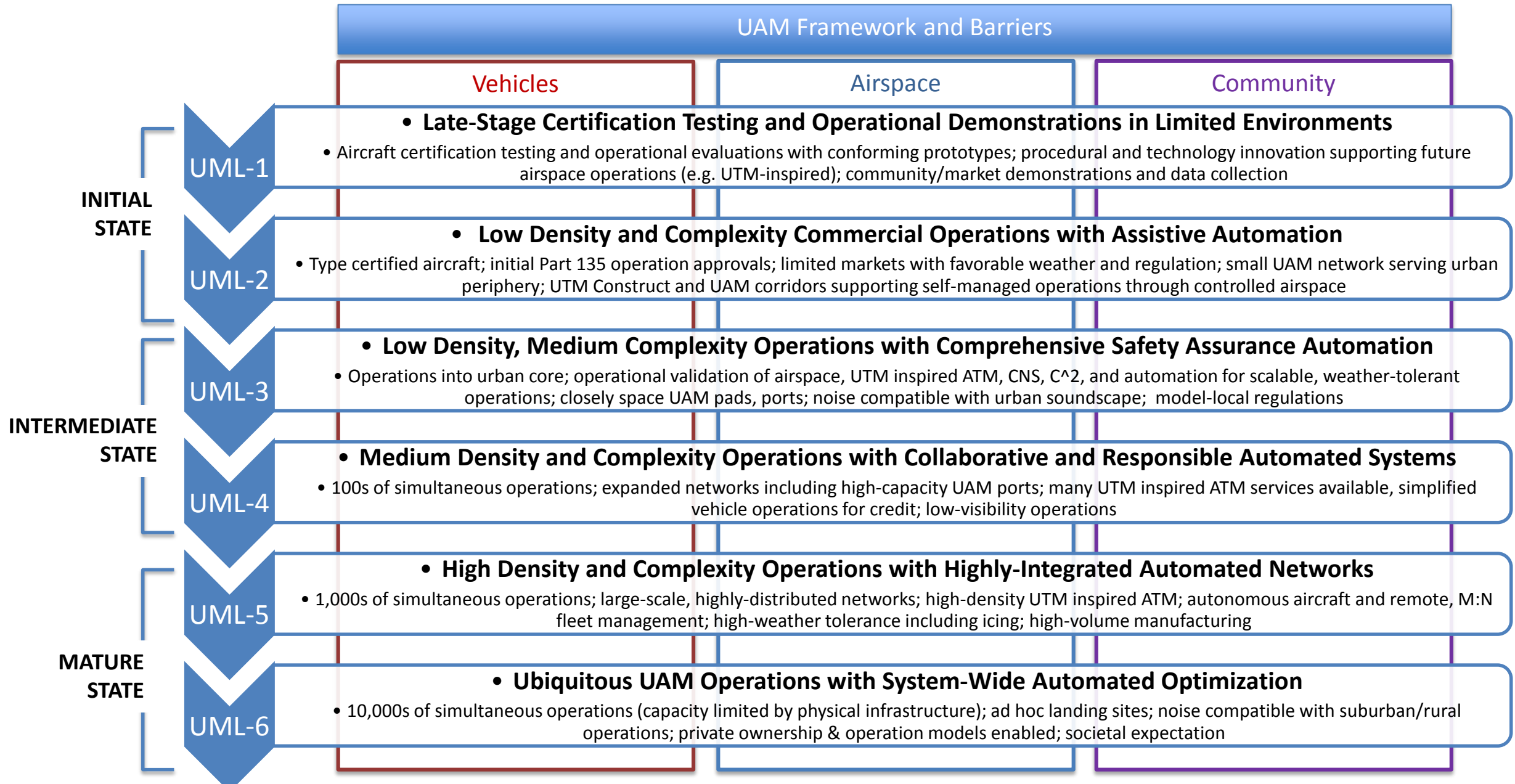
# NASA UAM Priorities

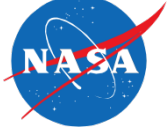


- Vehicle Barriers
- Airspace Barriers
- Community Integration Barriers
- # Pillar number



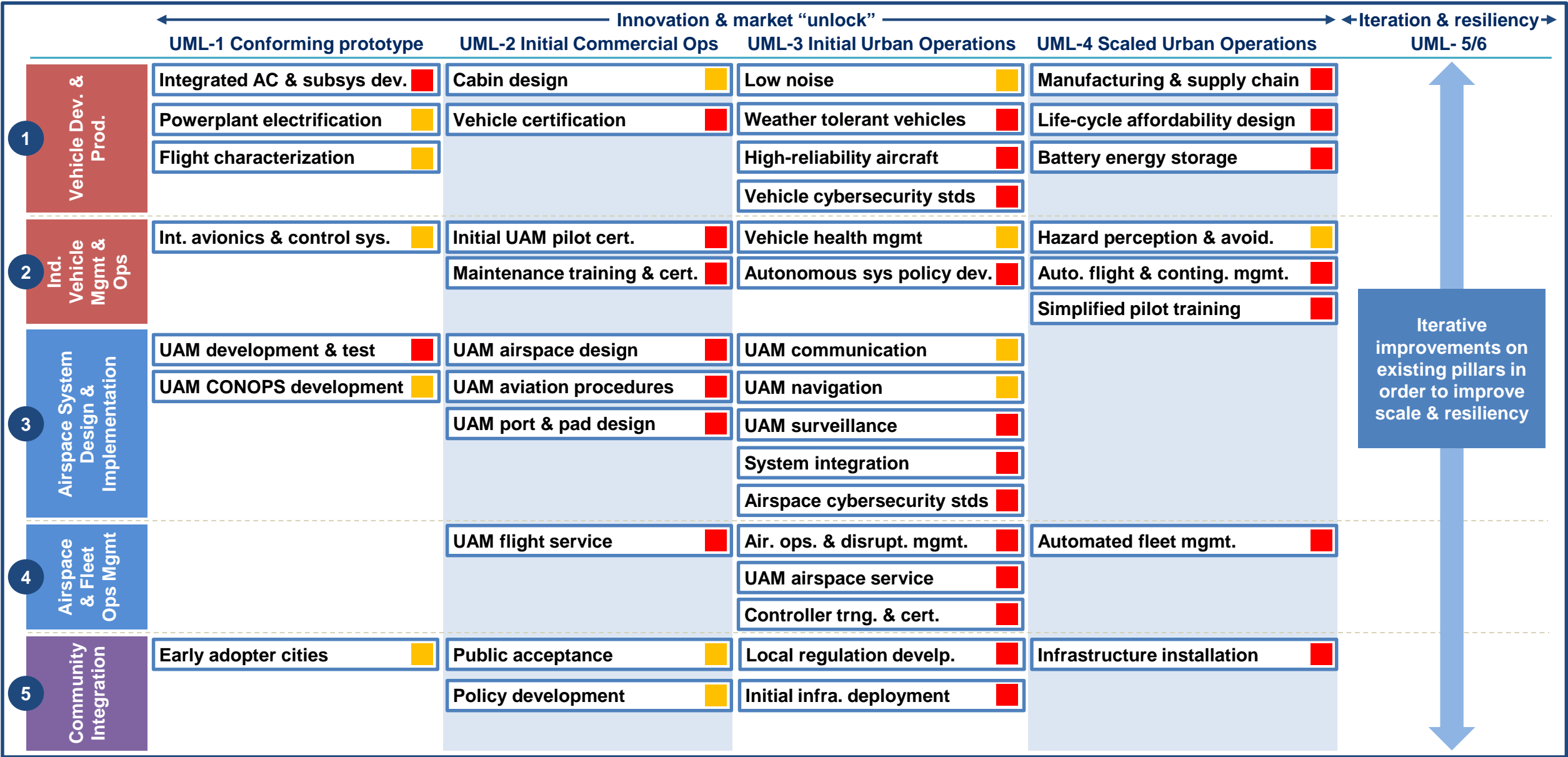
# UAM Maturity Levels (UML)





# Functions to “unlock” a UML

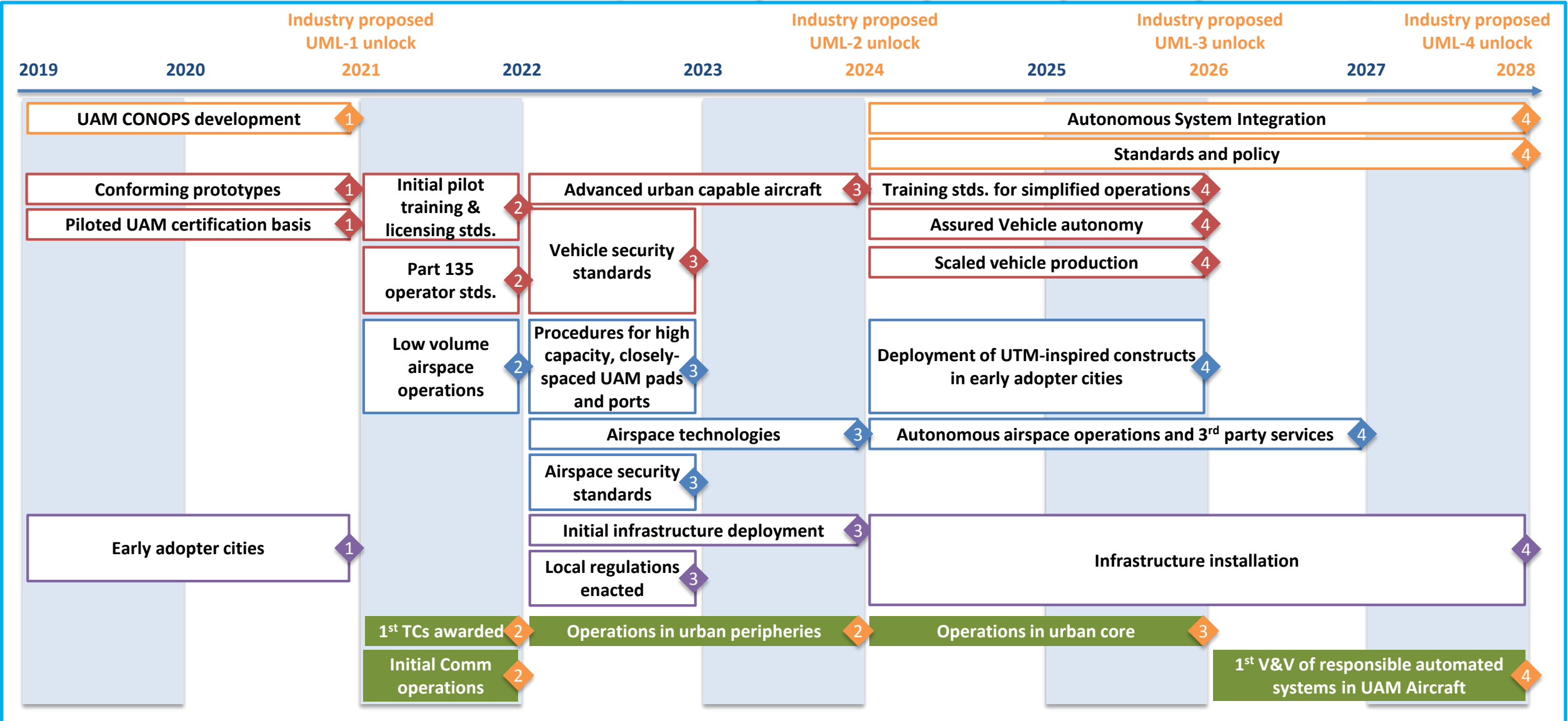
■ Significant work to reach maturity    
 ■ Moderate work to reach maturity    
 ■ Minimal work to reach maturity    
 ■ Assessment incomplete





# Representative industry UAM timeline<sup>1</sup> and milestones

# UML-#    ◆ Overarching    ◆ Vehicles    ◆ Airspace    ◆ Community    ■ Industry milestone



<sup>1</sup> Based on a range of publicly available industry projections; not a consensus view; aggressive