

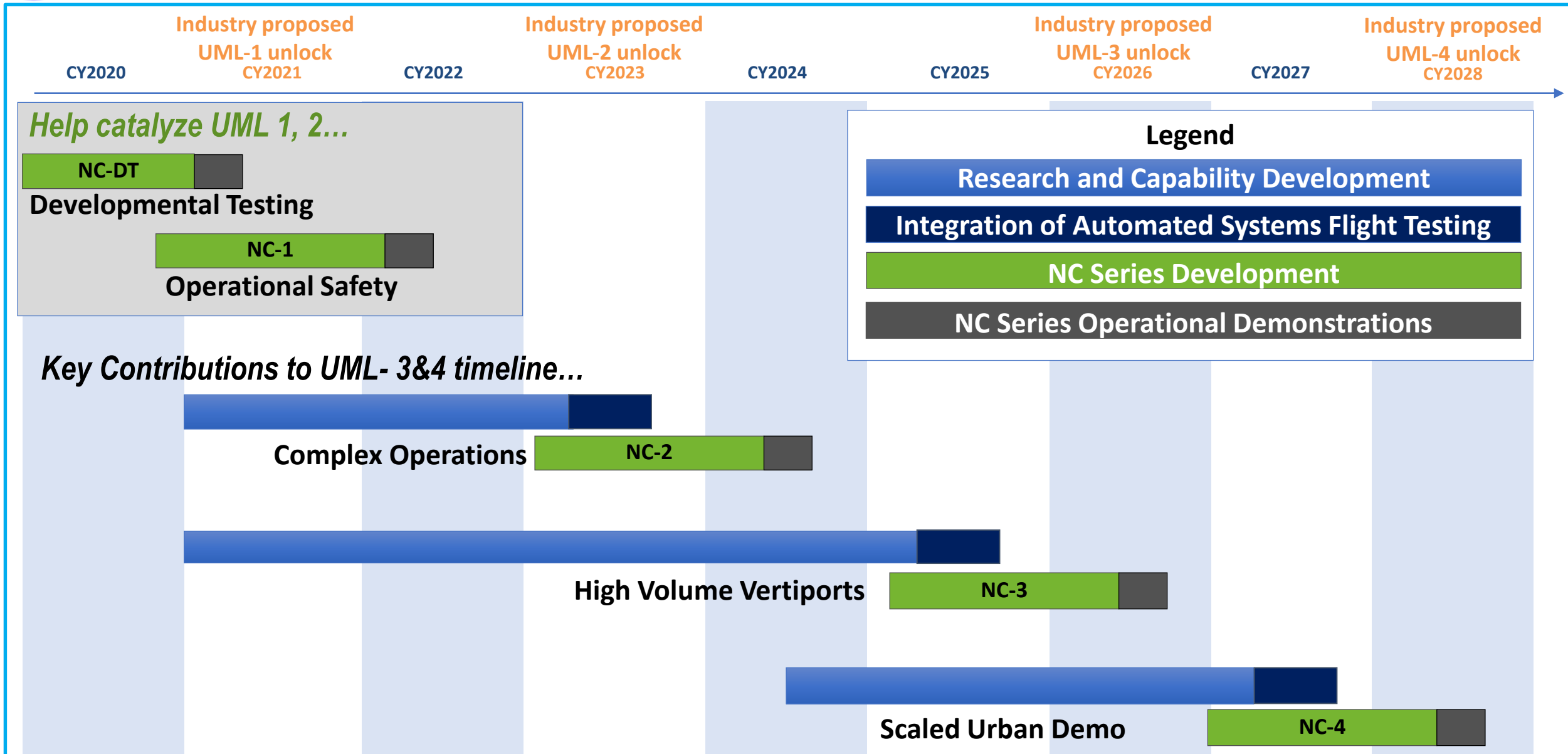


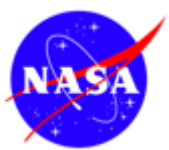
Advanced Air Mobility National Campaign
Boeing Information Exchange Meeting #2
May 20, 2020



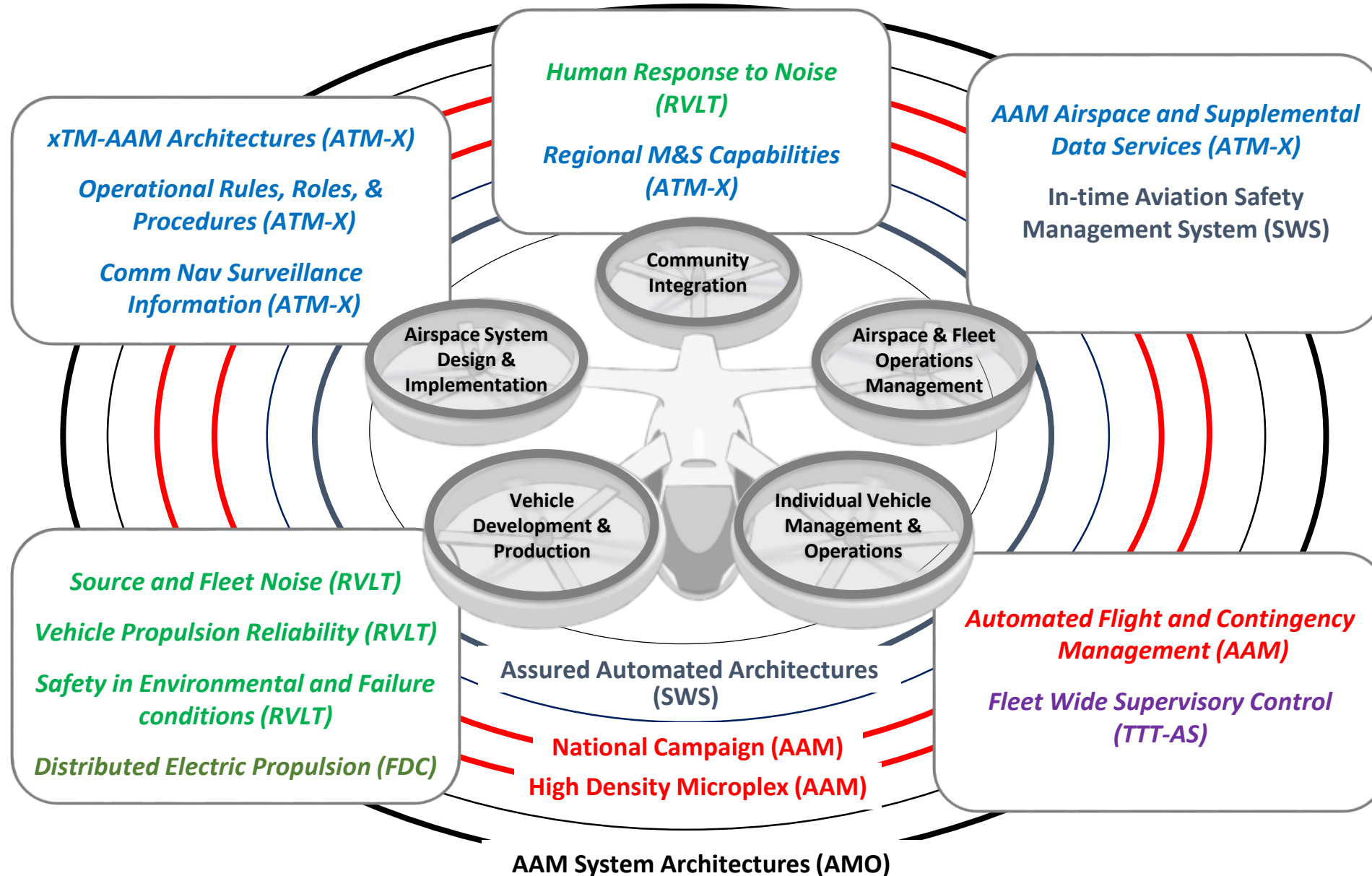


NASA AAM Mission Research to enable National Campaigns





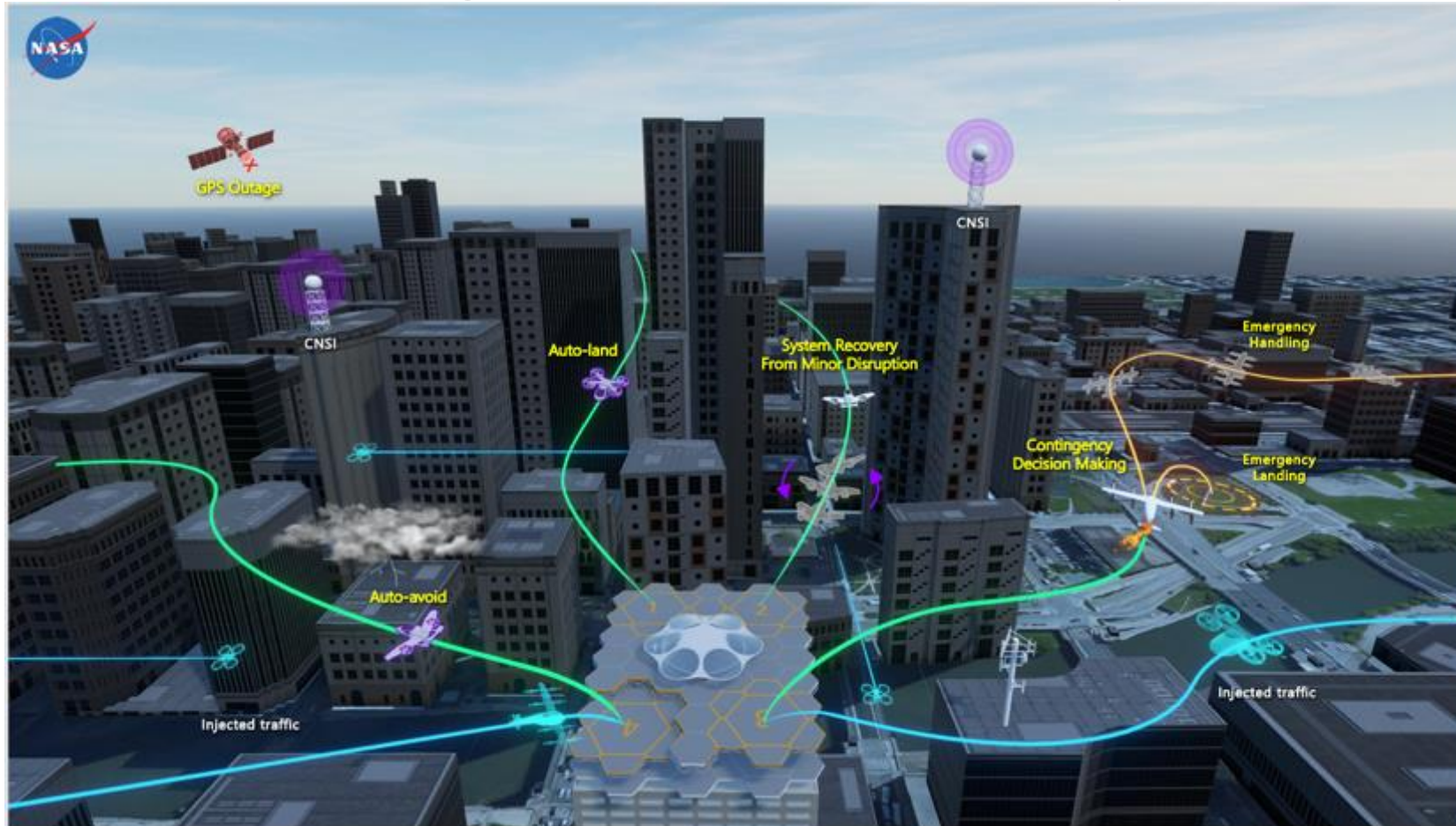
NASA AAM Mission Priorities



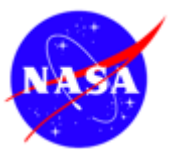
Lead Project Legend

AAM
ATM-X
RVLT
SWS
FDC
TTT
AMO

NC-3 High Volume Vertiports



- 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
- Etc....



MICROPLEX DEFINED

Airspace

Providing the appropriate constructs to enable:

- Airspace authorizations
- Routes and procedures
- Flight planning
- Traffic sequencing
- Data constructs for weather, NOTAM, TFR and other associated ANSP information



Bandwidth

Enable demand capacity balancing for increasing volumes of new entrants across various equipages. Through high precision performance bandwidth can be increased by reducing lateral separation requirements, reduced vertical separation requirements (ROC), and overall efficiency gains.

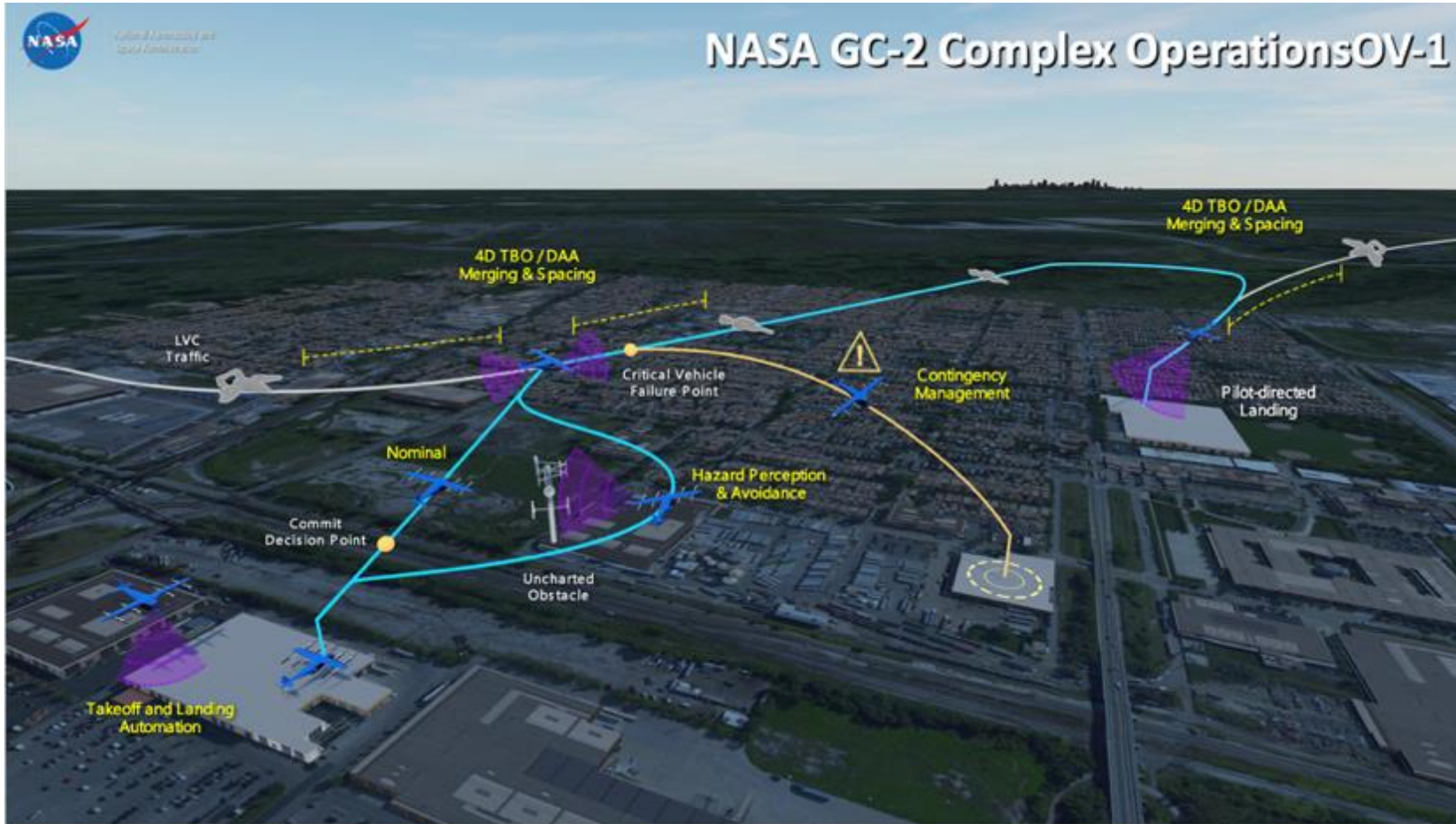


Contingency Management

The safety cases needed to enable a microplex hinge on contingency management operations and procedures that account for rerouting, lost Communication, Go-around / Missed Approaches, all land scenarios, and priority sequencing for landing.



NC-2 Complex Operations



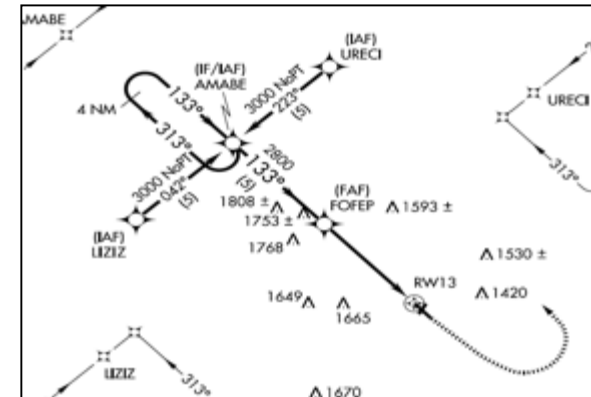
- Resilient air, ground, cloud CNSI
- UAM procedural leg library (TBO, 4D-TBO, Airborne M&S)
- Automated, arrival, approach and departure procedures
- Fail-operational, simplified vehicle controls and management
- DAA – airborne and surface hazards
- Adaptive trajectory planning and full-envelope auto-flight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



- # CONTROLLER



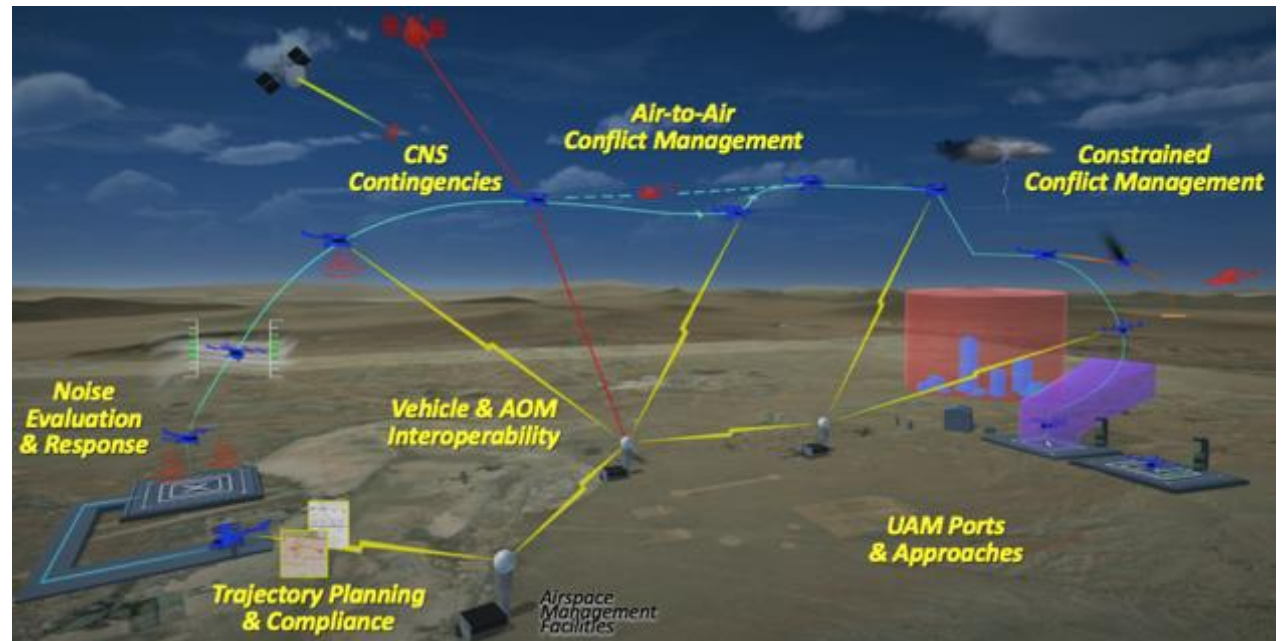
- # TERPSTER



- 1. Populate**
- 2. Evaluate**
- 3. Mitigate**

National Campaign Fundamentals

- Series Emphasis on Operational Scenarios, and remaining flexible to industry needs
 - NC-DT includes flights and simulations to validate scenarios and develop the proving ground in support of NC-1
 - NC-1 scenarios will be used to baseline operational expectations, and as a learning opportunity to identify gaps in AAM
 - NC-1 will move participants closer to operations
 - NC Series will progress into more difficult operational environments through targeted demonstrations
- Primary test ranges determined by location that partners plan to fly
- Ecosystem WG's will be the primary means for the entire community to provide inputs





UAM Helicopter Dry Run Objectives

- Demonstrate, and capture baseline data, from key flight characteristics maneuvers suitable for UAM vehicles
- Prove initial concepts, and capture baseline data, from envisioned UAM operational approaches/departures to/from UAM Terminals:
 - UAM Heliport
 - UAM Vertiport
- Demonstrate, and capture baseline data, from key “UAM Task Elements” (discrete, Closed-Loop “Building Blocks” of envisioned UAM mission profiles)
- Demonstrate, and capture baseline data, from UAM Scenario flights (end-to-end UAM sorties)
- Exercise Range/deployment support assets
- Exercise Airworthiness/Flight Safety Review process
- Develop Flight Test Plan for UAM Flight Vehicle studies

Subpart B Certification Standards

NASA/FAA Simulation studies

Vertiport Design Standards

Subpart G Certification Standards/UAM Airmen standards

NASA/FAA/Industry Handling Qualities Standards development

NASA/FAA Airspace studies

Risk Reduction for subsequent Work with UAM manufacturers



Objectives Flowchart NC-1 to NC-DT to NC-DT Dry Run

NC-1 Objectives

- Accelerate Certification and Approval
- Develop Flight Procedure Guidelines
- Evaluate the (CNS) Trade Space
- Demonstrate an Airspace Management Architecture
- Characterize Community Considerations

NC-DT Objectives

- Assess Maturity and Robustness of NC Proving Ground
- Assess Effectiveness of NC Testing Processes, Logistics, and Data Collection
- Preliminary Assessment of Partner Capabilities and Systems Performance
- Assess the Suitability of NC-1 Scenarios

- 1 Demonstrate Integrated Aircraft & Test Infrastructure
- 2 Demonstrate Deployable Integrated Test Infrastructure
- 3 Demonstrate connectivity and functionality between range assets and PSU Network
- 4 Demonstrate operations, procedures, and processes
- 5 Collect, Manage and Store Data
- 6 Demonstrate data handling, storage, sharing processes and hardware
- 7 Collection and distribution of weather data
- 8 Evaluate route design techniques between Area A site to the X-33 site.
- 9 Evaluate terminal area operations and procedures
- 10 Evaluate scenarios 1-3.



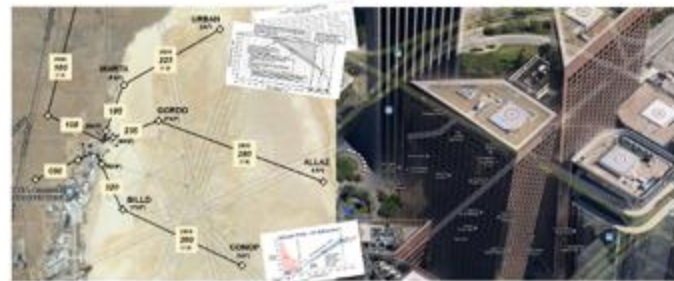
Dry Run Secondary Objectives

1. Evaluate candidate automatic flight rules precision approaches using an onboard FMS autopilot and FIAPA hardware and coding.
2. Demonstrate a vehicle datalink capable of beyond-visual-line-of-sight (BVLOS) operations such as Trac-Plus and/or a cellular/satellite internet modem
3. Evaluate real-time weather data collection and transmission hardware and procedures for use within the PSU network.



UAM Helicopter Dry Run

- Demonstration of “anchor” and “evolve” approach
- Purpose and Types of Tests



– Flight Characteristics –

“open loop” testing that closely mirrors existing certification tests – baseline test techniques and results will be compared to subsequent UAM test techniques and results – as UAM database/experience grows, it is expected we can evolve our quantitative vehicle standards with “defendable” (empirical) evidence

– UAM Task Elements –

“Building blocks” of UAM mission profiles – “closed loop” tests that look at discrete tasks under controlled environments – these tests are expected to feed development of qualitative evaluations that can support future certification findings for highly augmented, feedback control, flight vehicles

– Scenarios Testing –

“end-to-end” UAM missions that will provide the backdrop for testing and validating Airspace evolutionary concepts for managing the UAM economic model



Evolutionary steps for Vertical Flight...

Vehicles must exhibit Stability & Control characteristics appropriate for:

- UAM simulated Instrument Approaches to Heliport & Vertiport
 - 9 degree nominal glidepath
 - Constant deceleration/fixed glidepath approaches
 - Transitional lift approaches
- Low speed and Hover
 - All Azimuth requirements defined for the urban environment
 - Balked Landing/Missed Approach characteristics and airspace
 - (Apparent) Stability and Control/Margin

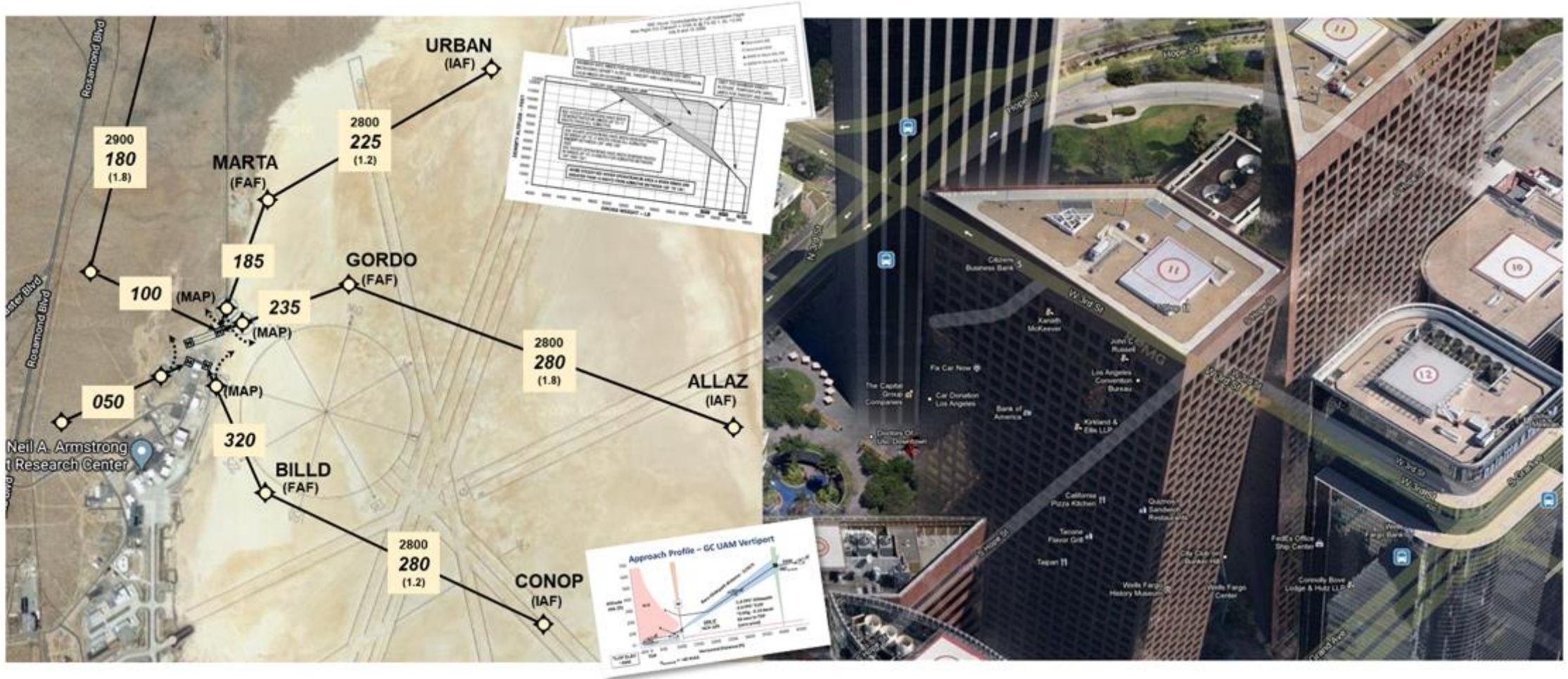
Vehicles must exhibit Performance appropriate for UAM Instrument Approaches

- Climb Performance/Continued Takeoff after failure (similar to Rotorcraft Cat A takeoff)
- Power Margin
- Fly Away/Return to TLOF capability (after failure)
- IGE/OGE hover performance capability

Vehicles must exhibit Handling Qualities suitable for the UAM mission

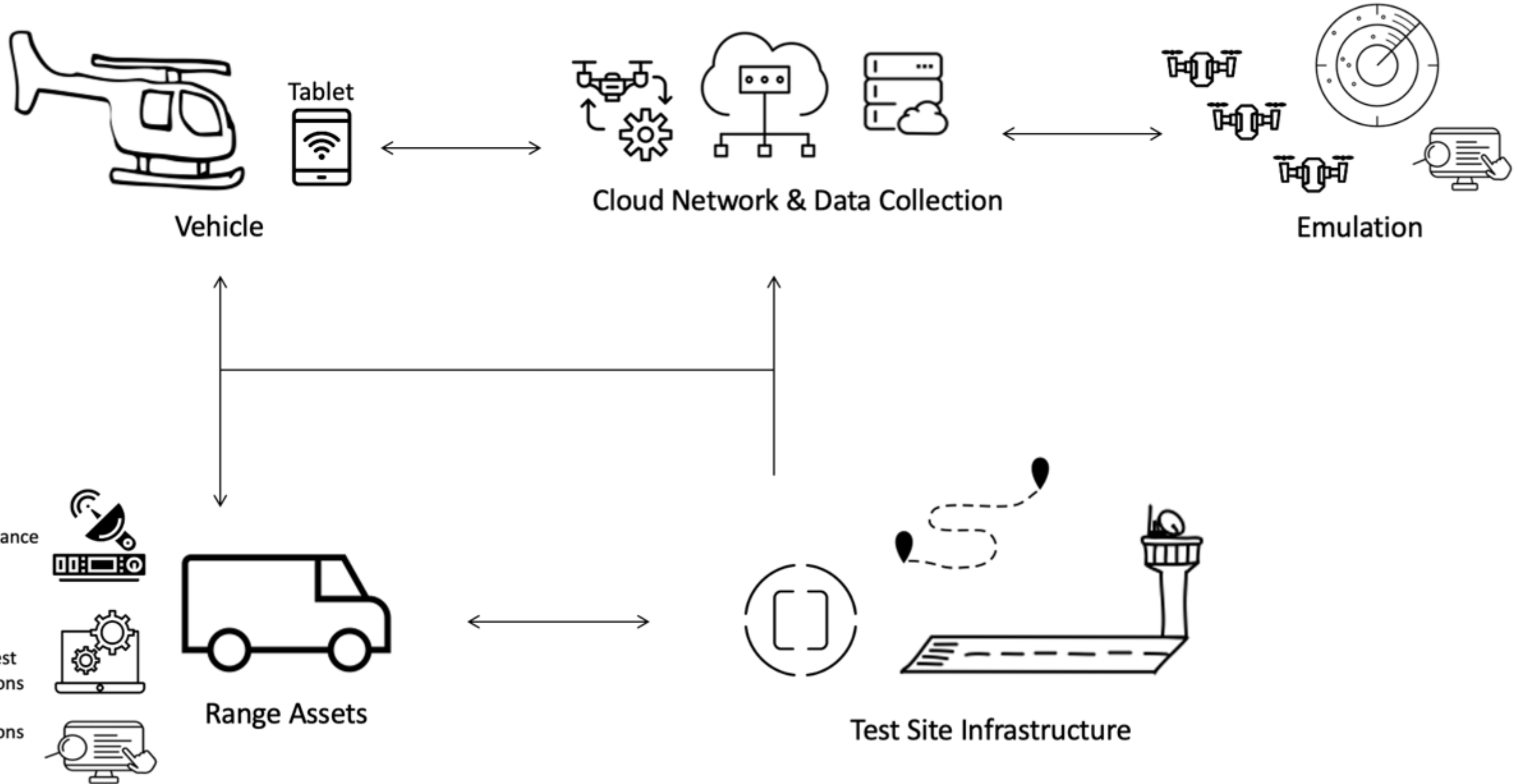


...to revolutionize Urban Air Mobility





AFRC Dry Run Flight Test Infrastructure



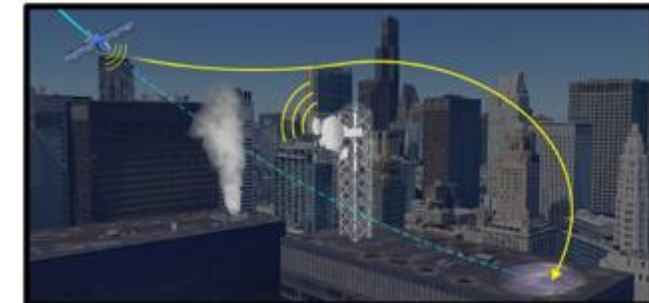
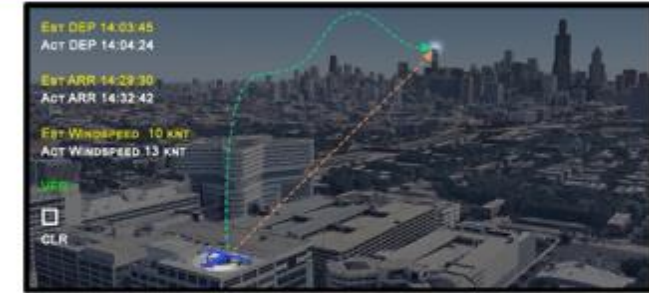
UML 1 (x): VMC, Piloted, Controlled/Uncontrolled, ports are located in uncontrolled or non movement areas if on airport surface. Break up by phase of flight

	Authoriza tion	Clearances	Flight Planning	Surface Ops	Arrival/Dep procedures	Notificati on/Messa ging (TFR)	Schedulin g	Flow Management for UAM* (GDP, EDCTs)	Airspace Separation	Contingen cy Manag	Airspa ce Struct ures	Weath er
Port Ops		Advisory for a non movement like area	Advisory	Prime	Primary – preferred UAM routes	Co-prime (NOTAM, ATIS)	2nd					
ANSP	Prime	Prime			Co-prime	Prime		Prime	Prime (in controlled)	Prime (in controlled)	Prime	
Vehicle												
Pilot	R	R	R	Co- prime	Co-prime	R	R	R	Co-Primary (as delegated by ANSP)*	Prime		Prime
Fleet Ops			Prime	2nd	2 nd	2 nd	2nd	2nd		2nd		Co- prime
PSU/UA M Ecosyste m	2nd – enable authoriza tion	2nd	2nd (discover y, intent)	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd
Other Users					Third party interest							



Dry Run Operations – Scenarios

- **Scenario 1: Nominal Integrated Flight Operations**
 - Nominal flight planning for a flight with no activated contingencies
 - Flight planning, route negotiation and acceptance, route and time conformance
 - Simulated background traffic to study impacts on timing
- **Scenario 2: Integrated Flight Operations with an Activated Contingency**
 - Nominal point-to-point route, then TFR requires the vehicle to re-route around it
 - ATi tablet is preferred method to indicate the re-route in flight, but will also be briefed, loaded in the GPS, and in the flight cards
- **Scenario 3: Terminal Operations and Approach/Landing Contingencies**
 - 3a: Airspace initiates the contingency; go-around, loiter, and land at original site
 - 3b: Vehicle initiates the contingency; balked landing and divert to an alternate site
 - 3c: Vehicle initiates the contingency; vehicle will execute a go-around, request immediate landing, and ATC will work into simulated traffic to land on an active runway
- **Vehicle Characteristics**
 - More traditional flight tests to inform vehicle certification standards



NASA-FAA Data
Elements Workbook



Track Objectives
for UAM
Implementation

Identify Data
Attributes for
Procedures

Research & Analysis	Ops Concepts & Req'mts	Standards	Procedures	Airspace	Systems	Policies	Security	Oversight Processes	HR Mgmt & Trng	Outreach & Communication	Int'l Outreach & Engagment
Airspace Research	Ops Concepts, Scenarios, & Req'mts Development	Airworthiness Certification Standards	Air Traffic Operations Procedures	Charting	ATM/CNS Systems/Capabilities	Air Traffic Policy	Cyber Security	Auditing Air Traffic & Navigation Services	ATO Training	Aviation Industry Outreach	Harmonization w/FAA Concepts, Rules & Procedures
Capabilities & Systems Research		Pilot School Certification Standards	Pilot in Command Procedures	Facility Maps	Support Systems	CFR Rulemaking AVS 10/31/18	Physical Security	Accident/Incident Investigation & Reporting	Flight Standards Training	General Public Outreach	Int'l Relationship & Outreach
Policy & Regs Research		SVO Airman Certs/Quals	Flight Stds Procedures				Waivers & Exemptions	UAS Detection and Tracking	Airports Traning	Outreach & Coordination with Federal, local and Tribal Gov	Bilateral Agreements & other
Procedures Research		Flt Instr Certs/Quals	Airport Procedures				Acs & Guidance	Remote ID	Resource Management	Internal FAA Outreach	
Standards Research		Training Center Certification Standards	Manufacturers Procedures				Environmental Policies				NEPA Compliance
Training Research		Operator Certification	Owner Procedures							Communications Management	
Aircraft Certification Research		Maintenance Standards	Security Procedures							State & Local Law Enforcement Assistance Program.	
Air Traffic Management Research		Repair Station Standards	Hazardous Materials								
Environmental Research		Mechanic/Repariman Standards									
Security Research		Maintenance School Standards									
Safety Analysis		C2 Standards									
		DAA Standards									
		Environment Standards									
		Remote ID Standards 3.2.4 P/U (6-30-20)									
		Continued Op'l Safety Standards									

Grand Challenge Data

1. Operational Objectives

a. Trajectory and flight intent conformance

b. Telemetry/p

c. Takeoff and

d. Landing accu

e. Constant air

f. Operating co

i. Density altit

temperatures th

at TO, winds alof

g. Energy Rese

h. Time to turn

i. Operational this section

j. Maturity of from the Vehicle

i. Examples: Do Flight changes, r timelines

k. Thermal mar operationally ex

l. Maturity of Practical Procedu

m. Time to establish connection between the airspace and vehicle systems

2. Timeliness Objectives

a. Vehicle pre-flight

b. Vehicle taxi or tow to ramp (start of movement and conclusion of movement)

c. Vehicle power-up

d. Takeoff

e. Transition to forward flight

f. Beginning of cruise

g. Midpoint of mission

h. End of cruise

i. Transition to landing mode

j. Immediately after landing

k. Vehicle shutdown

l. Quantify time to "quick-turn" the aircraft for a new flight

Grand Challenge Data

Example: CG to Clear Obstacles – NASA Grand Challenge

$$CG = \frac{O - E}{0.76D} = \frac{2526 - 2285}{0.76 \times 1.47} = 215.71 \approx 216 \text{ ft./NM}$$

O = Obstacle MSL elevation ft.
E = OCS start elevation MSL
D = Distance (NM) OCS origin to obstacle

*Assumed: 200 FPNM CG – OCS 40:1
300 FPNM CG – OCS 20:1
400 FPNM CG – OCS 15:1

Map for Analysis
to Characterize &
Integrate New
Entrants and Ops