UAM Grand Challenge Virtual Meeting

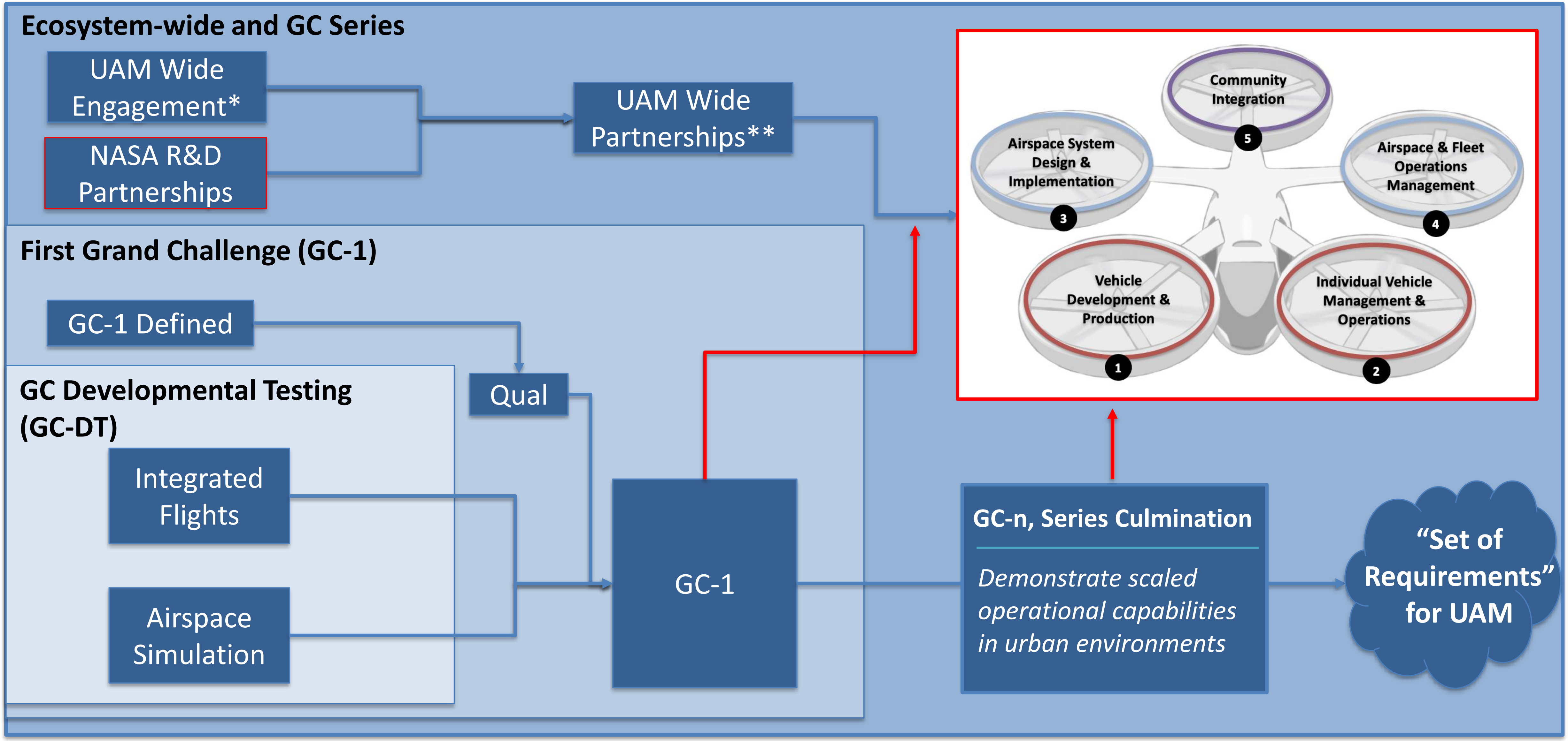
August 27, 2019

Webinar Purpose

Provide updates on NASA's internal progress related to Grand Challenge planning

- Explain how the Grand Challenge will benefit the entire UAM ecosystem
- Discuss how the Grand Challenge series fits into community milestones
- Discuss in detail the next steps related to Grand Challenge series
- Explain the mechanics of participating in the Grand Challenge (e.g., agreements)
- Introduce working groups and solicit participation

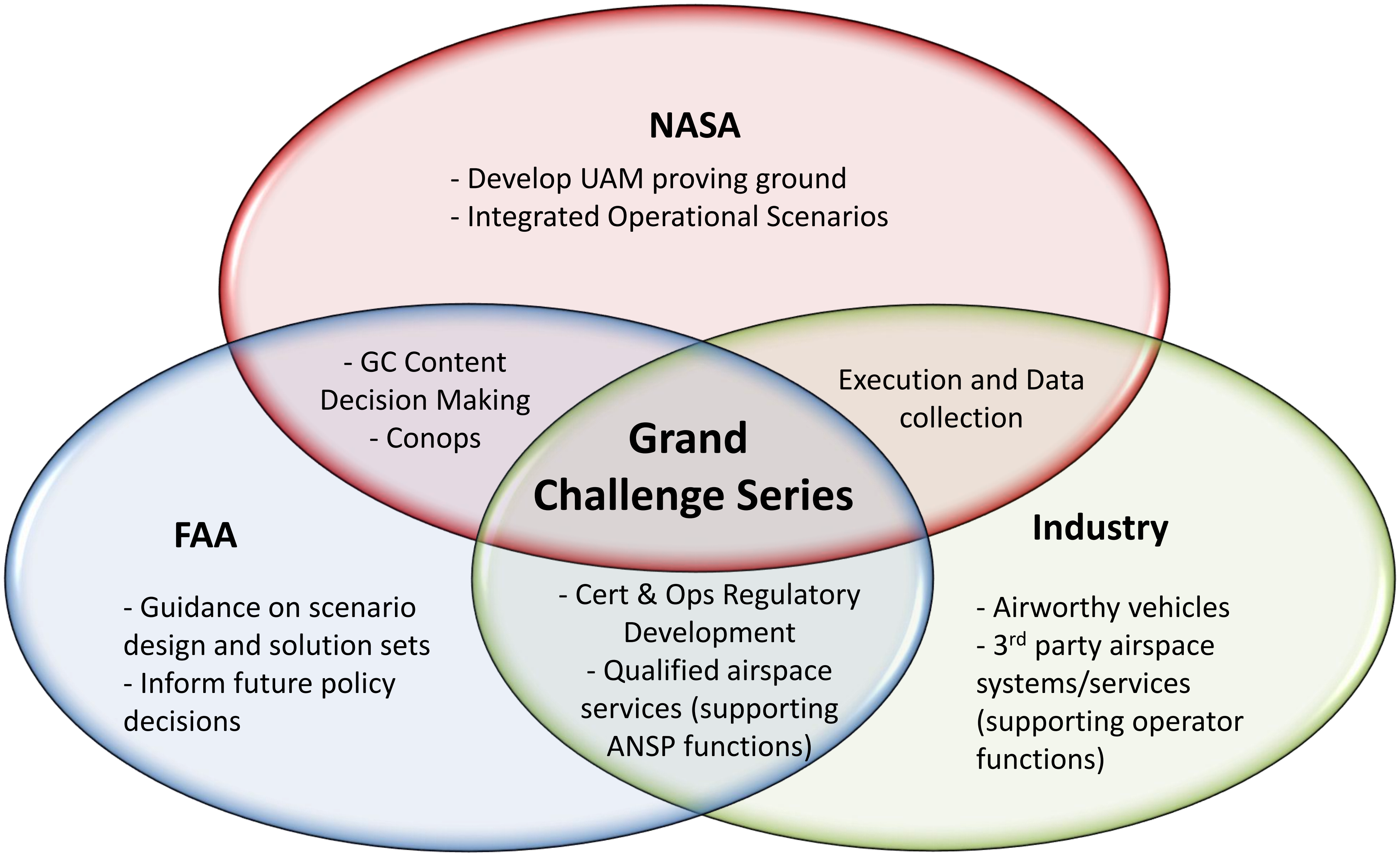
Partnership and Grand Challenge Series Overview



*Continue to work future GC definition through collaborative partnership workshops

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

NASA/FAA/Industry Relationship for Grand Challenge Series



Note: Future Grand Challenges also include a more focused Community perspective

NASA/FAA/Industry Relationship for Grand Challenge Series

NASA/FAA Team consist of many individuals across both agencies

FAA: main POCs from ATO, ANG, AFS, AIR, AUS, and ARP

NASA: 11 main individuals working the GC

Improve, refine use-cases, and/or add to the UAM Grand Challenge scenarios

- Define the operating environment (both real and simulated) in which the scenarios will take place (e.g., which airspace class(es))
- Define the concept of operations that will be tested (e.g., what does digital messaging look like?, how segregated vs integrated are the ops?)
- Be clear about “near-term” vs “farther-term” use cases
- Consider wake-related issues (categorization for novel aircraft and separation standards)
- Consider an “all land” scenario
- Ensure we are collecting data to assist with pilot certification and increasing levels of automation/autonomy (SVO)
- Consider airspace operational priority from things like medevac
- How can we gather and report hyper-local weather conditions to aircraft/airmen?
- Consider how geofencing would work in degraded CNS scenarios
- Ensure vehicle performance data can be used for vertiport standards work / tie with Tech Center RFI on this topic
- Ensure that if we need exemptions from regs for the actual GC flights (e.g., reserve fuel) that we consider those early

Next Steps incorporate industry feedback to above

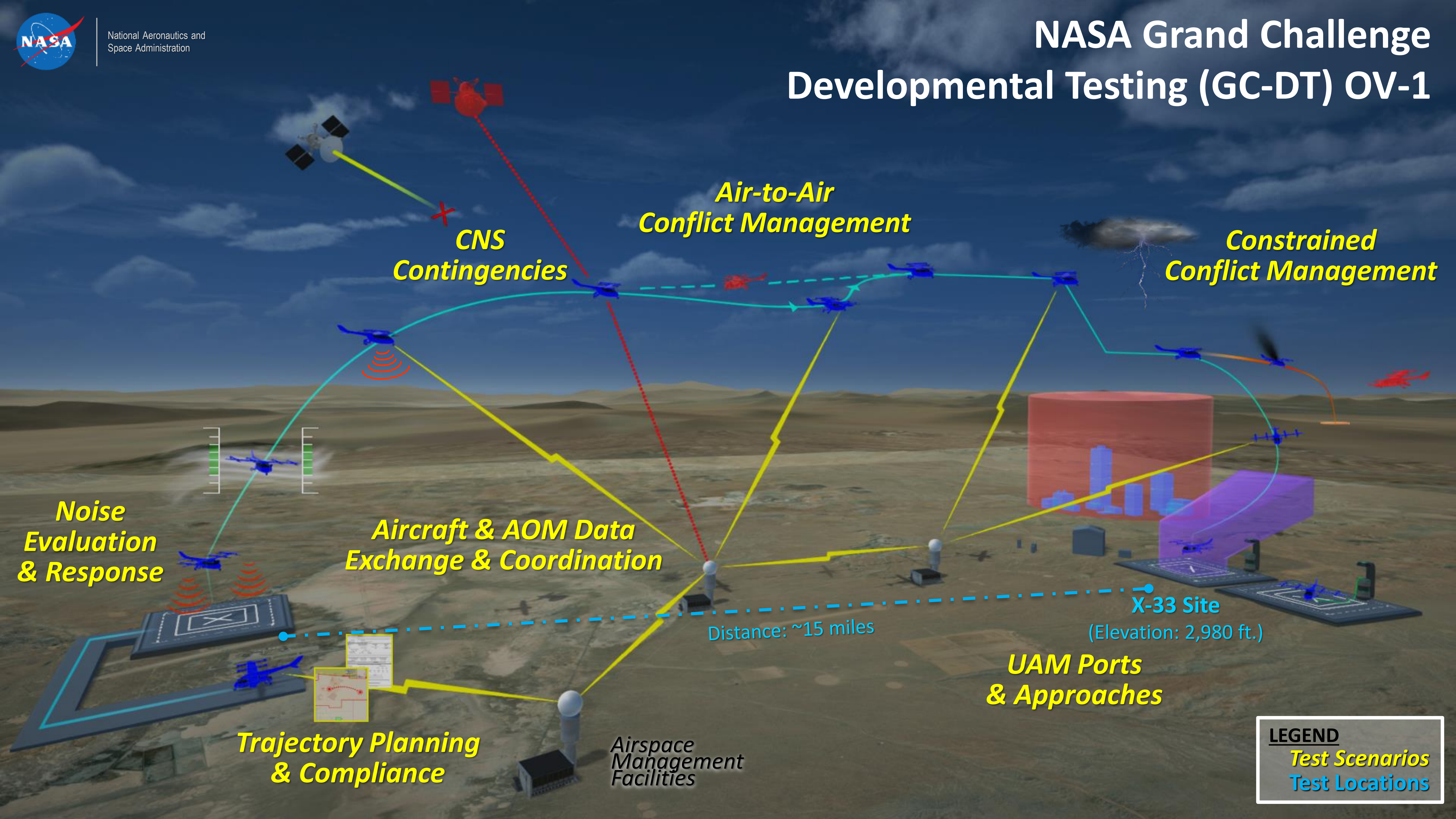
Grand Challenge 1 Goals & Objectives

Goal

Support requirements and system development for scalable, commercial UAM through integrated demonstrations of realistic operational scenarios

Objectives

1. **Accelerate Certification and Approval.** Collect relevant data through flight test techniques that assist the FAA in standardizing test procedures, data requirements, and methods of compliance for UAM vehicle certification, operator certification, and operational approval, including considerations for increasing levels of automation and autonomy
2. **Develop Flight Procedure Guidelines.** Test different flight procedures and related airspace design constructs that enable the development of preliminary flight procedure guidelines and airspace design criteria
3. **Evaluate the CNS Trade-Space.** Explore and evaluate reliable, secure and affordable communication, navigation, and surveillance requirements, options, and trade-offs
4. **Demonstrate an Airspace Operations Management Architecture.** Demonstrate expansion of the UTM construct and document an airspace operations management architecture that has the potential to safely manage scalable UAM operations without burdening the current ATM system
5. **Characterize Community Concerns.** Conduct initial characterization of the community noise impacts of UAM vehicles through measurements of vehicle ground noise

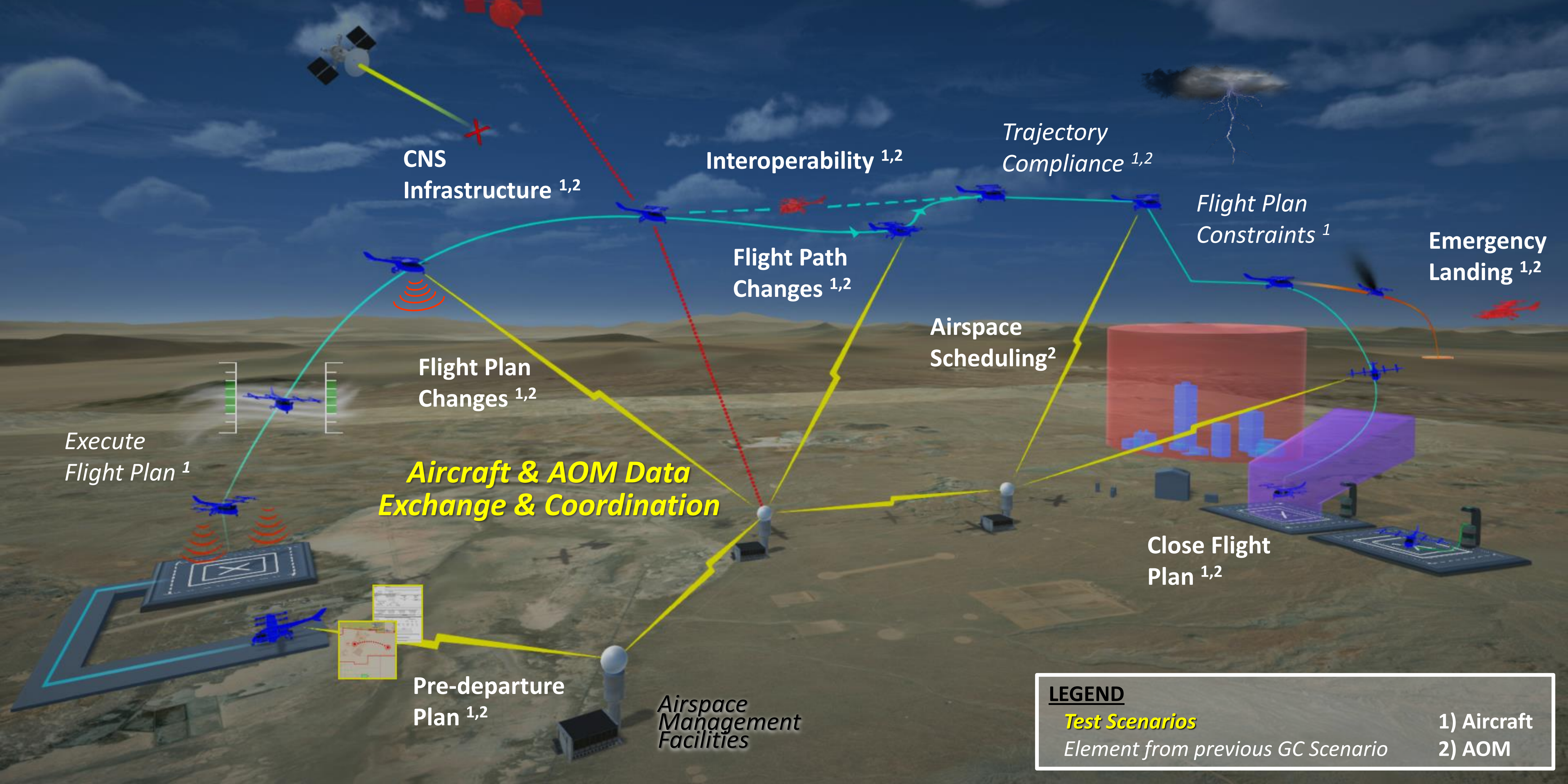


National Aeronautics and Space Administration
NASA Grand Challenge Developmental Testing (GC-DT) OV-1
CNS Contingencies
Air-to-Air Conflict Management
Constrained Conflict Management
Noise Evaluation & Response
Aircraft & AOM Data Exchange & Coordination
Distance: ~15 miles
X-33 Site
(Elevation: 2,980 ft.)
UAM Ports & Approaches
Trajectory Planning & Compliance
Airspace Management Facilities
LEGEND
Test Scenarios
Test Locations

National Aeronautics and Space Administration

Vehicle and AOM Interoperability Scenario

Objective 4: Demonstrate an Airspace Operations Management Architecture

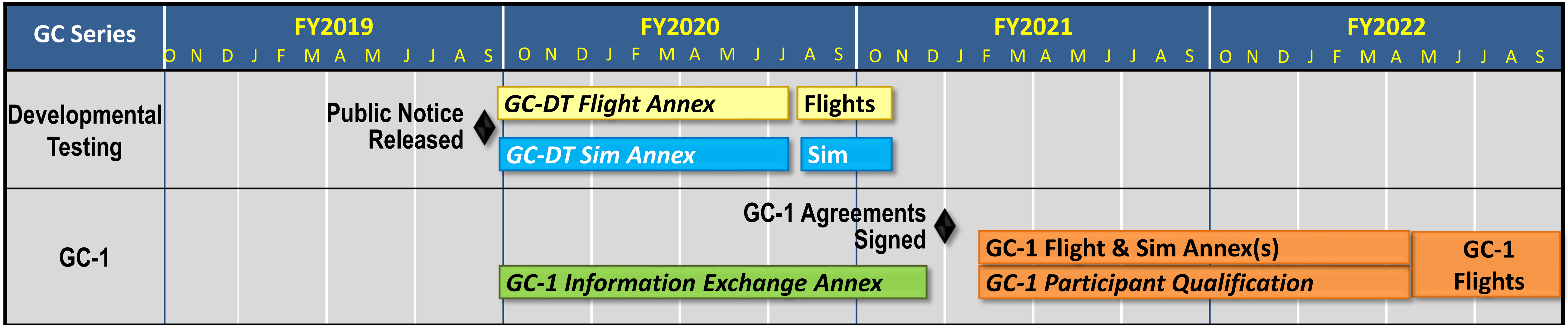


Flow Down of Data Collection Requirements

- Goals and Objectives
  - FAA Standards to be informed by UAM Operations
    - Associated Scenario UAM Task Elements (UTE)
      - Method of recording data
        - Test Safety Data Gathering and Reporting
        - Differential GPS/Inertial Measurement Unit (Partner to integrate)
        - Two-way Fiber Network to UTM API (Partner to integrate)
          - Update rates
        - Range Safety
          - UHF/VHF Radio (Partner provided)
          - ADS-B (Partner provided)
          - C-Band Beacon (Partner to integrate)
          - Video Recording
          - Voice Recording
          - Flight Termination System if needed (Partner to integrate)
            - requires TM from vehicle and vehicle dynamic state data
        - ATI Recorded UTM/Vehicle scheduling and separation with background traffic
        - Acoustic
        - Aircraft Operational manual (Partner provided)

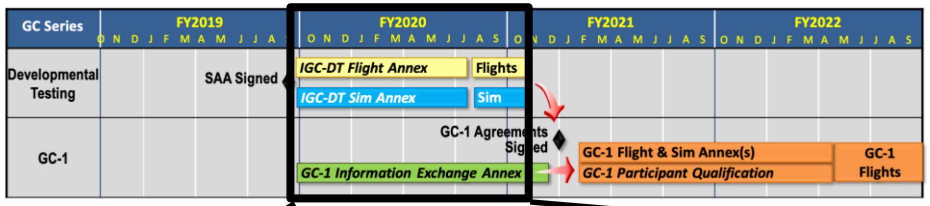
Next Steps

Timeline (gov't fiscal year)



- GC Events
  - Announcement of Collaborative Partnership Opportunities planned release in September 2019
  - GC-DT flights and simulation in ~July-Nov 2020
  - GC-1 flights with live simulations in ~May-Sept 2022
- Non-Reimbursable Umbrella Space Ace Agreements (SAAs)
  - Three Annex of partners: GC-DT Flight, GC-DT Simulation, GC-1 Information Exchange
  - Close GC-DT Flight participants annex ~end of Oct 2019 to achieve desired GC-DT timelines
  - Close GC-DT Sim participants annex ~end of December 2019 to achieve desired GC-DT timelines
  - Close GC-1 Information Exchange ~end of December 2020
  - New public notice for GC-1 agreements to be released ~Jan 2021

GC Developmental Test Timeline FY19-FY20



This is correct- *Demonstrate compliance with UTM interface and complete approvals for flight*

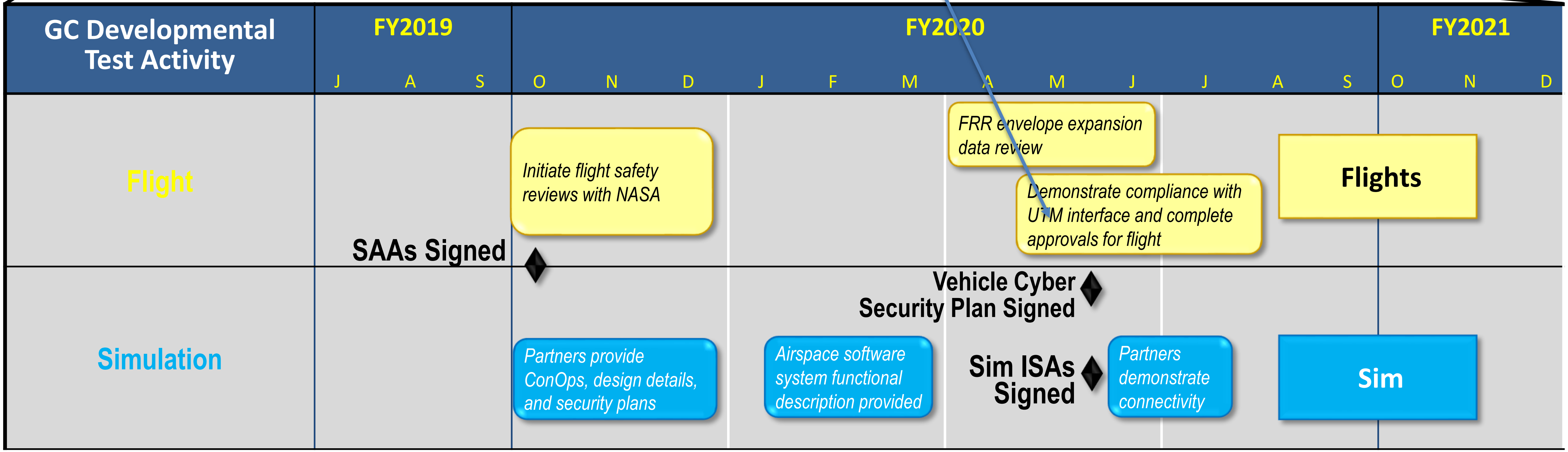
<u>NASA Resources to assist partners</u>

Flight Safety Review Liaison

Cyber security plan

Interconnect security agreements

Simulation Liaisons



Requirements for SAAs

- GC-DT Flight
  - Vehicle Size, Configuration, and CONOPS
  - Vehicle Maturity and Capabilities by GC-DT
  - GC-DT Participation Plans
  - Compliance with Umbrella SAA and Annex templates
- GC-DT Sim
  - Compliance with current GC Testbed Interface Control Document
  - Functional UAM Airspace Management System
  - Compliance with Umbrella SAA and Annex templates
- GC-1 Information Exchange
  - Vehicle Size, Configuration, and CONOPS
  - Compliance with Umbrella SAA and Annex templates

Next Steps

- Review Federal Register announcement
- Vehicle and Airspace participants that sign any of the three annex's will be apart of the solutions based Scenario input for Developmental Testing 2020 and GC-1 2022
- Test sites or sub-system providers that are partnered with a Vehicle company, and the Vehicle company is signed up for GC-1, are invited to participate in the solutions based scenario input

Other information for SAAs

- Grand Challenge Announcement of Collaborative Opportunity:
  - Umbrella SAA to cover participation through GC-1. Annexes are:
    - GC-Development Test Flight Annex (Agreements must be signed no later than Dec 2019)
      - Domestic U.S. vehicle companies that propose to fly in GC-DT in 2020
      - Limited participation – Select 3-4 participants
      - Preference for flights at ARFC, although will accept any U.S. range
      - Preference for companies that partner with U.S. airspace companies
    - GC-Development Test Airspace Annex (Agreements must be signed no later than Dec 2019)
      - Domestic U.S. vehicle companies for airspace simulations in GC-DT in 2020
      - Open participation – Limited criteria – Accept anyone that qualifies – U.S. only
      - Includes live flight option with certified vehicle at external range
    - GC Vehicle Provider Information Exchange Annex (open through end of 2020)
      - Early information exchange with vehicle companies to get ready to fly in GC-1 in 2022
      - Open participation for vehicle providers – Open to domestic and foreign companies

Other information for SAAs

- NASA will provide a Flight Readiness Board for remotely piloted UAM vehicle that affect ground, flight, range, and public safety
  - Avionics/Flight Systems
  - Aerodynamics
  - Flight Controls and Dynamics
  - Structures
  - Operations
  - FTS/Range Safety
- NASA will provide a Flight Readiness Board for piloted UAM vehicles that effect the pilot as well as ground, flight, range, and public safety
- The partner will comply with the Unmanned Aircraft System (UAS) Traffic Management (UTM) API to interface with the NASA systems and any other interfaces that NASA defines for the GC-DT activity, and provide real-time flight data during execution of GC-DT scenarios in accordance with the UTM API
- NASA will Assist Simulation and Vehicle Partners in developing Interconnection Security Agreement in accordance with NIST 800-47.
- NASA will Collect acoustic measurements of the Partner UAM vehicle during execution of the GC-DT acoustics (and other) scenarios. Process the raw experimental noise measurements by applying calibrations and corrections, and verifying data integrity to calculate a final set of processed acoustics data, and provide vehicle acoustic data to Partner.

Approach to Eco System Wide Working Groups

Working Groups call for action

- Look for a follow on public notice in the coming months for workshops / working groups
  - Broad community strategic input on Grand Challenge scenarios and other topics around certifying the airmen, aircraft, airspace, autonomy, infrastructure and noise
- Starting point is focused on definition of grand challenge – validate scenarios that will address industry's immediate and longer-term needs
  - Identify and collaborate on opportunities where other flight tests could be conducted to support ecosystem maturity consistent with grand challenge theme
  - Validate, adjust and finalize grand challenge scenarios that will meet industry's needs better (seek industry inputs in Grand Challenge scenarios and approach)
  - Identify additional critical areas that Grand Challenge is a tool to collect data
- <u>Working Groups</u> ensure the UAM ecosystem can achieve a "UML-4 book of requirements"
  - Identify and address requirements that are necessary to mature ecosystem (e.g., noise, airspace, aircraft autonomy, etc.)

FAQs for Working Groups

- Which other government organizations are expected in this group?
  - FAA, FCC, DOD, DHS, DOI, and DOJ/FBI
- Can an organization join the working groups even if we don't have aircraft or airspace system ready for (initial) Grand Challenge?
  - Yes, and you will be expected to contribute significantly just like everyone in terms of developing requirements, validating scenario details and test conditions, and other details
- Can an organization join the working groups later?
  - Yes, and you will be expected to contribute significantly at any stage you join
- Can an organization join the working groups even if they are users of the entire system (e.g., airline)?
  - Absolutely, they are one of the key stakeholders and their needs will need to be represented in the Grand Challenge and other research

BACK-UP

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

Preface NASA/Industry/FAA UAM Predecessors (not all inclusive)

- *NASA/DOD Fly-by-Wire Verified and Validated* Highly Automated Flight Controls – 4 decades of projects
- *NASA Green Flight Challenge* - flew 200 miles using just over a half-gallon of fuel equivalent per passenger
- *NASA LEAPTECH* – showed feasibility of DEP wing having Coefficient of lift up to 6
- *NASA X-57* – Demonstrating potential of DEP to significantly reduce energy consumption at high-speed cruise conditions, without sacrificing low-speed flight capabilities. Working with FAA AIR and ASTM to provide lessons learned for new electric propulsion technologies and safety cases for nonexistent standards
- *NASA ODM Roadmapping Workshops* – demonstrated the large community of interest that exists around on-demand mobility and featured key early feasibility studies showing the potential of UAM
- *NASA UAS in NAS* – developing Detect and Avoid, Command and Control standards to enable routine UAS access to the NAS
- *NASA UTM* – proving a system that would not require human operators to monitor every vehicle continuously, but provide strategic decisions related to initiation, continuation, and termination of airspace operation
- *NASA/OUSD Resilient Autonomy* - develop a robust architecture and methodology for certifying fully autonomous systems by using a technique known as multi-mode run-time assurance or MM-RTA.
- *FAA EZ-Fly* - demonstrating a simplified flight path-based Advanced Flight Control System, while using affordable fusion of sensors, control laws, displays, and a simplified pilot interface with full-envelope protection

UAM Maturity Levels (UML)

UAM Framework and Barriers (GC Series Focus)

Vehicles | **Airspace** | **Community**

INITIAL STATE

- **UML-1**: Late-Stage Certification Testing and Operational Demonstrations in Limited Environments
- **UML-2**: Low Density and Complexity Commercial Operations with Assistive Automation

INTERMEDIATE STATE

- **UML-3**: Low Density, Medium Complexity Operations with Comprehensive Safety Assurance Automation
- **UML-4**: Medium Density and Complexity Operations with Collaborative and Responsible Automated Systems

MATURE STATE

- **UML-5**: High Density and Complexity Operations with Highly-Integrated Automated Networks
- **UML-6**: Ubiquitous UAM Operations with System-Wide Automated Optimization

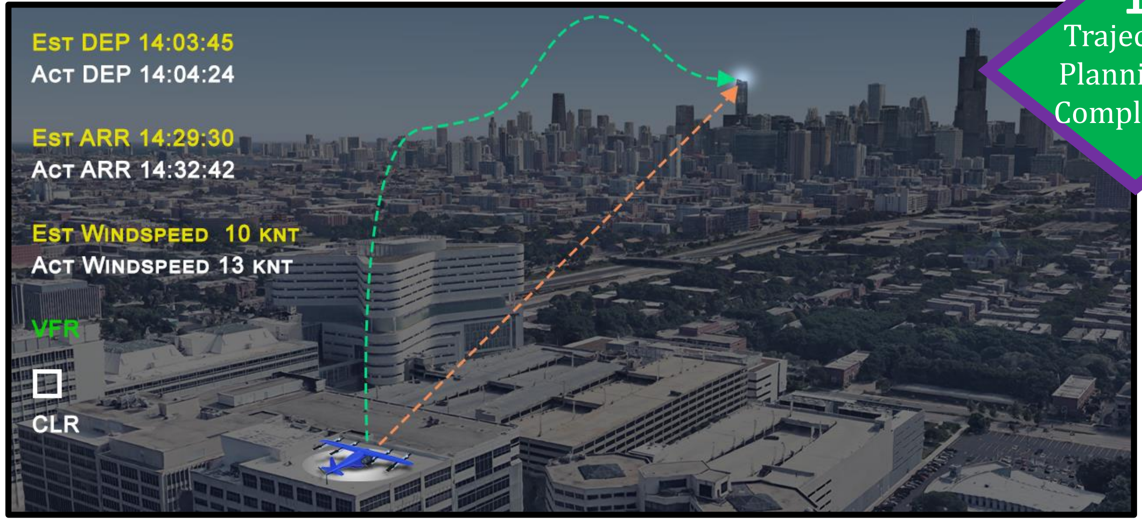
Qualification Testing ("Scenario 0")

Prior to participating in the Initial Grand Challenge, participants will have to demonstrate successful completion of the qualification activities, which must include:

- Vehicles:
  - Perform tests and document performance for the Directed Test Procedures for Mission Task Elements (MTEs) *TBD* (likely 1-13)
    - Allow NASA/FAA observation of tests (although observation may not occur)
  - Demonstrate connectivity to airspace operations management system
  - Pass range & ground safety, airworthiness (for manned vehicles), and flight safety reviews
- Airspace:
  - Provide system design documentation
  - Verify system connection
  - Successfully perform system simulation, documenting performance for UAM Elements *TBD*
  - Demonstrate connectivity to vehicle

Scenario 1 – Trajectory Planning & Compliance

Flight and operation planning for nominal operations that accommodates airspace operations management (AOM) system and aircraft constraints as well as precision of aircraft trajectory conformance to the flight plan across a range of density altitudes. Evaluate format for exchange of trajectory information between aircraft and AOM system.



1 Trajectory Planning & Compliance

IGC Aircraft Functional Objectives

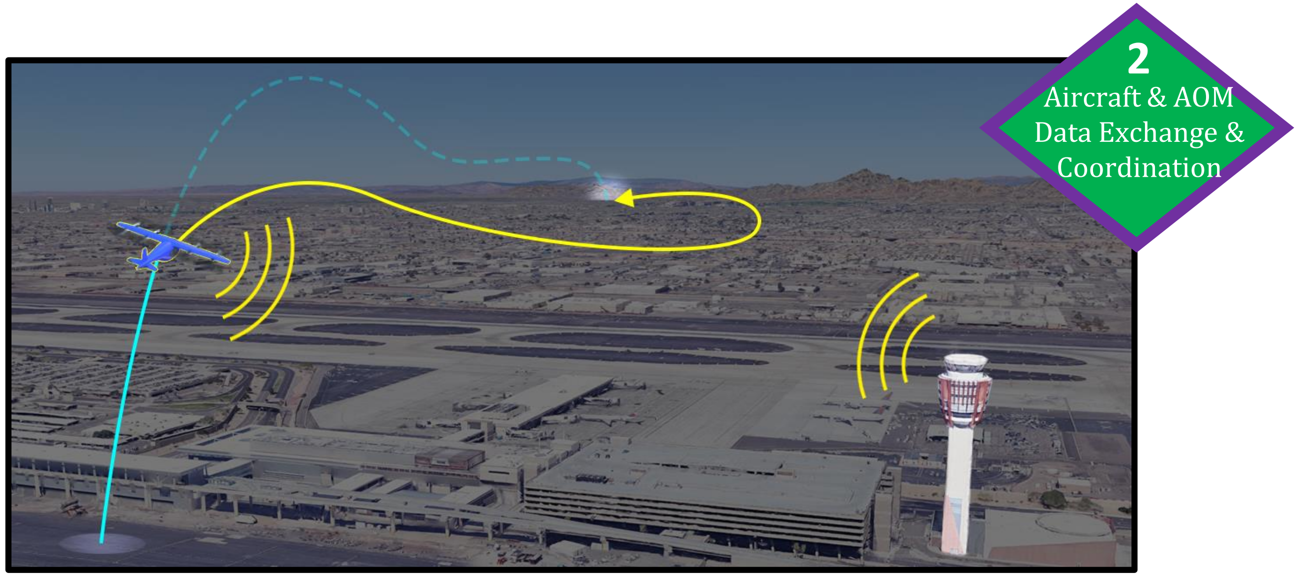
- Airspace Data Exchange – Demonstrate transmission to the ground of aircraft state, flight plan and revisions, etc. per a UTM ICD.
- Pre-departure Plan – Pre-departure flight plan generated, submitted and negotiated and accepted.
- Execute Flight Plan – Takeoff at pre-approved time and execute approved flight plan (via closed loop guidance and control) while continually reporting required trajectory and ETA, while attempting to maintain the original schedule.
- Trajectory Compliance – Evaluate laterals, altitude and time variations from intended 4-D route plan, in dynamic environmental conditions.
- Flight Plan Constraints – Evaluate ability of aircraft to comply with known pre-flight airspace and scheduling constraints.

IGC Airspace Functional Objectives

- Pre-departure Plan – Pre-departure flight plan negotiation with aircraft including; Scheduled Time of Arrival slots, weather, airspace constraints and vertiport information.
- CNS Infrastructure – Demonstrate Communication Navigation Surveillance infrastructure, weather infrastructure and other operational needs for 4D trajectory planning, tracking and monitoring.
- Trajectory Compliance – Evaluate laterals, altitude and time variations from intended 4-D route plan, in dynamic environmental conditions

Scenario 2 – Aircraft & AOM Data Exchange & Coordination

In-flight re-planning, negotiation and execution that accommodates airspace operations management (AOM) system and aircraft constraints, and responds to real-world uncertainties. Exercise exchange of trajectory information, AOM system and aircraft constraints, and user preferences between aircraft and airspace management systems.



IGC Aircraft Functional Objectives

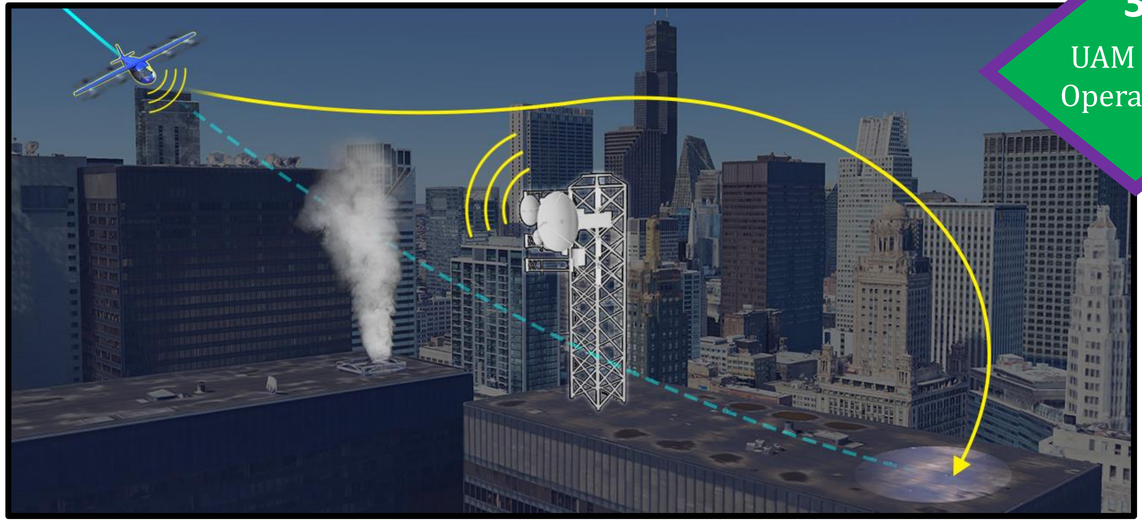
- All functional objectives from Scenario 1 apply to Scenario 2.
- Flight Plan Changes – aircraft receives and responds to AOM system advisories for in-flight changes of planned routes, including: new scheduled time of arrival, new landing location, etc.
- Flight Plan Changes – aircraft generates and requests in-flight trajectory changes and negotiates with AOM system.
- Interoperability – Evaluate airspace and aircraft system interactions with communications and negotiations.
- Flight Path Changes – MTE 5 nominal flight path performance will be evaluated, including energy reserves.
- Emergency Landing – Demonstrate emergency landing, including communication with AOM system.

IGC Airspace Functional Objectives

- All functional objectives from Scenario 1 apply to Scenario 2.
- Flight Plan Changes – AOM system generates, sends and negotiates updated advisories (directly or indirectly) to the aircraft in-flight. E.g., new scheduled time of arrival, new landing location, conflict management, new routing, etc.
- Flight Path Changes – AOM system receives and responds to in-flight trajectory changes from the aircraft.
- Interoperability – Evaluate airspace and aircraft system interactions with communications and negotiations.
- Flight Path Changes – Trajectory conformance to the negotiated clearance will be evaluated.
- Emergency Landing – AOM system responds to aircraft declaration of emergency by clearing required airspace and making appropriate reroutes

Scenario 3 – UAM Port Operations

Develop scalable UAM Port design and procedures, and explore influencing factors such as turn-around times, ground operations, airspace scheduling impacts around UAM ports, localized weather information, and impacts of balked landings/go-arounds.



IGC Aircraft Functional Objectives

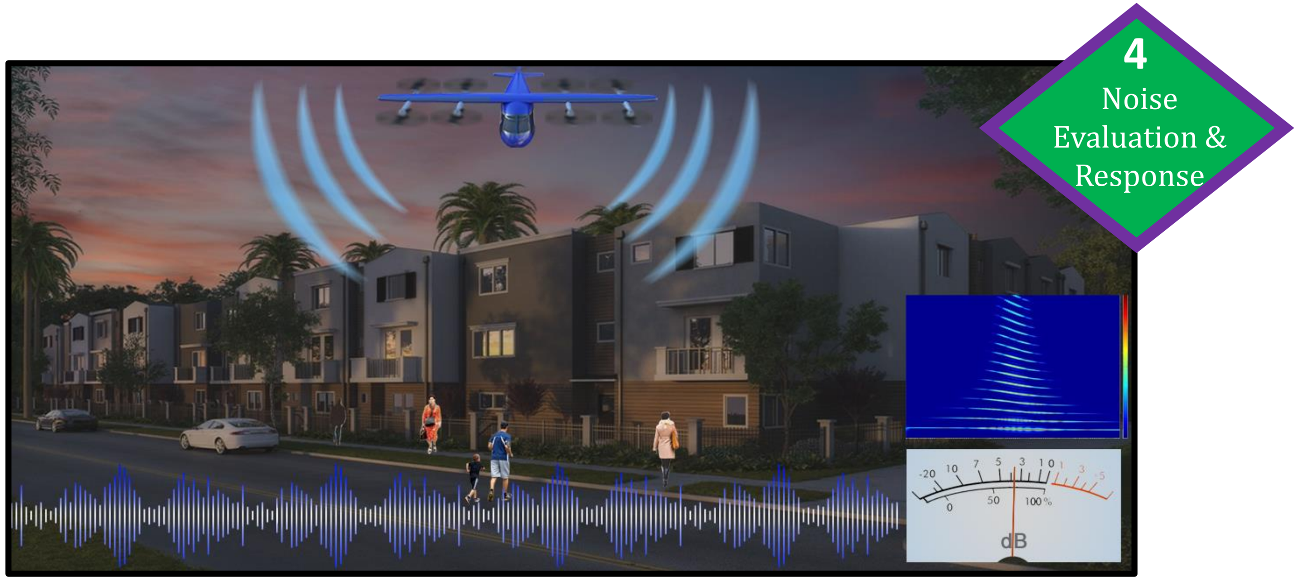
- UAM Port Procedures - Demonstrate UAM Port Procedures that include approach, landing, surface operations, take-off, departure, Actual Navigation Performance (ANP) / Required Navigation Performance (RNP), sequencing, holding patterns, operations at closely spaced UAM ports and pads, and stationary obstacles (e.g. trees, buildings, telephone poles and lines, power lines, water tower, etc)
- Turn-around Operations – Demonstrate time to launch a prepped aircraft from "cold" start and time to quick-turn the aircraft for new flight and evaluate mission-planning system including mission turn-around, recharge/refuel, servicing and ground maintenance, aircraft pad and passenger occupancy time, etc.
- Port Design – Develop and Evaluate other best practices for fire safety, downwash considerations, first responder access, closely spaced ports, etc
- Terrain and other obstacles (i.e., ground collision avoidance) – Demonstrate ability to perform conflict resolution maneuvers with awareness to surrounding obstacles and terrain
- Balked Landing – Demonstrate ability to perform a balked landing, including touchdown at original landing pad, through a variety of dynamic environmental conditions.

IGC Airspace Functional Objectives

- UAM Port Procedures - Demonstrate UAM Port Procedures that include approach, landing, surface operations, take-off, departure, Actual Navigation Performance (ANP) / Required Navigation Performance (RNP), sequencing, holding pattern, operations at closely spaced UAM ports and pads, and stationary obstacles (e.g. trees, buildings, telephone poles and lines, power lines, water tower, etc)
- Scheduling - Evaluate throughput of UAM port operations considering aircraft turnaround times, closely spaced UAM ports and pads, airspace and port capacity, traffic flow management, fleet resource optimization, and density of landing/takeoffs
- Weather information – Measure wind for crosswind check. ATM system broadcast measurements to aircraft.
- Terrain and other obstacles – Demonstrate ability to generate conflict resolution advisories providing awareness of surrounding obstacles and terrain
- Balked Landing – AOM system demonstrates ability to safely and efficiently provide the aircraft that performed a go-around another approach/landing attempt.

Scenario 4 – Noise Evaluation and Response

Evaluate aircraft noise and response through typical UAM mission flight profiles, including takeoff, climb, transition, cruise, descent, and landing. Exercise integrated (aircraft and airspace) planning, in-flight modification, and execution of low noise flight trajectories and profiles to minimize fleet noise impacts from UAM operations.



IGC Aircraft Functional Objectives

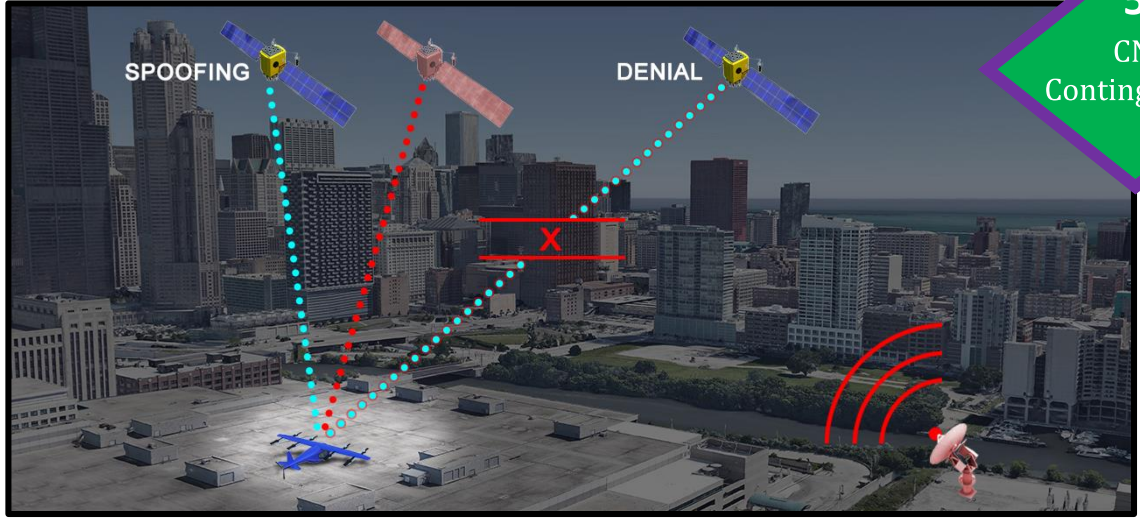
- Noise Characterization – Measure aircraft noise through standard flight conditions, maneuvers and profiles, including takeoff/landing, transition, cruise, etc. Precise and repeatable flight conditions flying over a microphone array.
- Noise Variability – Measure the effect of dynamic environmental conditions (winds, turbulence, altitude, etc.) on the noise produced by UAM aircraft.
- Low Noise Flight Profiles – Calculate and demonstrate flight profiles (all phases of typical UAM missions) to minimize noise exposure on the ground towards minimizing fleet noise impacts in the areas of UAM aircraft operations. Integrate local atmospheric measurements and predictions into the calculation of low noise flight profiles and/or accept low noise flight profile from AOM service(s).
- Community Response – Assess community response to noise exposure from UAM aircraft using the noise measurements for the aircraft included in the Grand Challenge.

IGC Airspace Functional Objectives

- Flight Profile Planning – Demonstrate prediction and planning of low noise flight profiles within the airspace management system. Integrate local atmospheric measurements and predictions into the calculation of low noise flight profiles, as well as considerations for the time of day.
- Flight Profile Impact – Evaluate the impact of low noise flight profiles and trajectories on airspace system performance (efficiency, predictability, throughput).
- Noise Exposure Management – Demonstrate multi-aircraft flight plan prediction and management to minimize the fleet noise impact in areas of UAM aircraft operations.

Scenario 5 – CNS Contingencies

Identification, mitigation, and response to contingencies related to degradation/loss of primary aircraft navigation, aircraft and airspace communications, and/or airspace surveillance. Exercise ConOps that incorporate robust, reliable, and fault tolerant CNS system, including the ability to safely land in event of failure(s).



5
CNS Contingencies

IGC Aircraft Functional Objectives

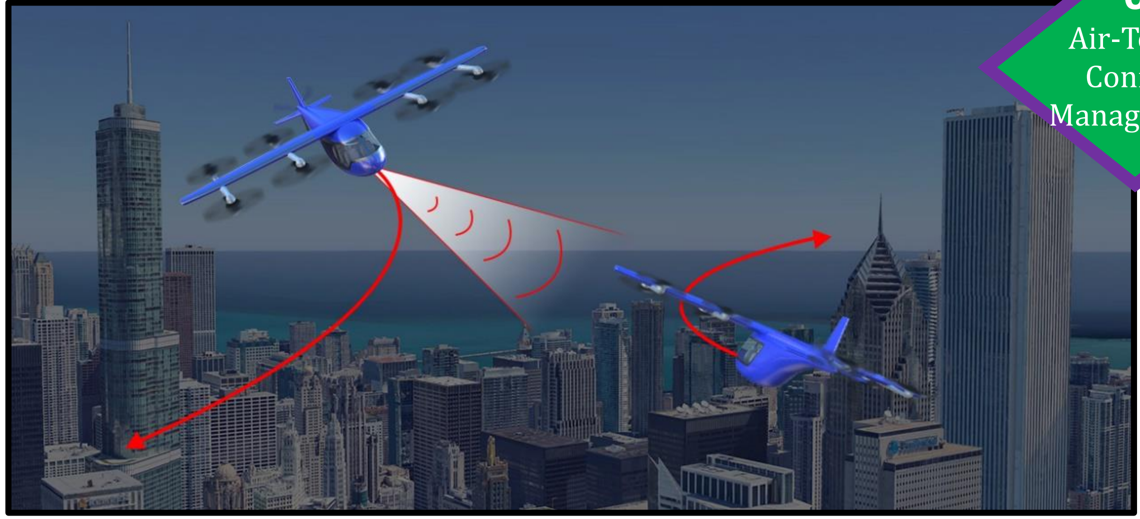
- Degraded Navigation – Evaluate system response and accuracy to primary navigation system sensor jamming/denial/degradation. Participant to simulate loss of primary navigation system upon NASA command, and use backup to execute response strategy.
- Aircraft Lost Link – For remotely piloted aircraft, loss of aircraft communication / control from the ground station. Demonstrate ability to recover from loss of communications.
- Airspace Lost Link – For all aircraft, loss of communications between aircraft and airspace systems. Demonstrate aircraft and mission procedures for loss of communications.
- Airspace Interoperability – Appropriate coordination with airspace management system in response to CNS contingency situations.
- Automation – Demonstrate automatic aircraft control and procedures in response to CNS contingency situations.
- Precautionary/Emergency Landing – Through a variety of dynamic environmental conditions, demonstrate precautionary landing with an on-board system failure.

IGC Airspace Functional Objectives

- Degraded Navigation – Evaluate airspace system response to loss of precision navigation of as single or multiple aircraft following a loss of their primary navigation system.
- aircraft Lost Link – Evaluate airspace redundancy plan based on ConOps for loss of communications with one or more aircraft, accommodation of non-conforming aircraft, real-time response to aircraft that do not follow current instructions.
- Degraded Surveillance – Evaluate airspace system response and mitigation procedures to loss of surveillance of aircraft in small or large areas of operations.
- aircraft Interoperability – Appropriate coordination with aircraft and the ATM in response to CNS contingency situations.
- Precautionary/Emergency Landing – AOM system responds to aircraft declaration of emergency by clearing required airspace and making appropriate reroutes

Scenario 6 – <u>Air-to-Air Conflict Management</u>

Demonstrate individualized components of traffic conflict management in order to evaluate interplay between essential layers of separation assurance and collision avoidance



IGC Aircraft Functional Objectives

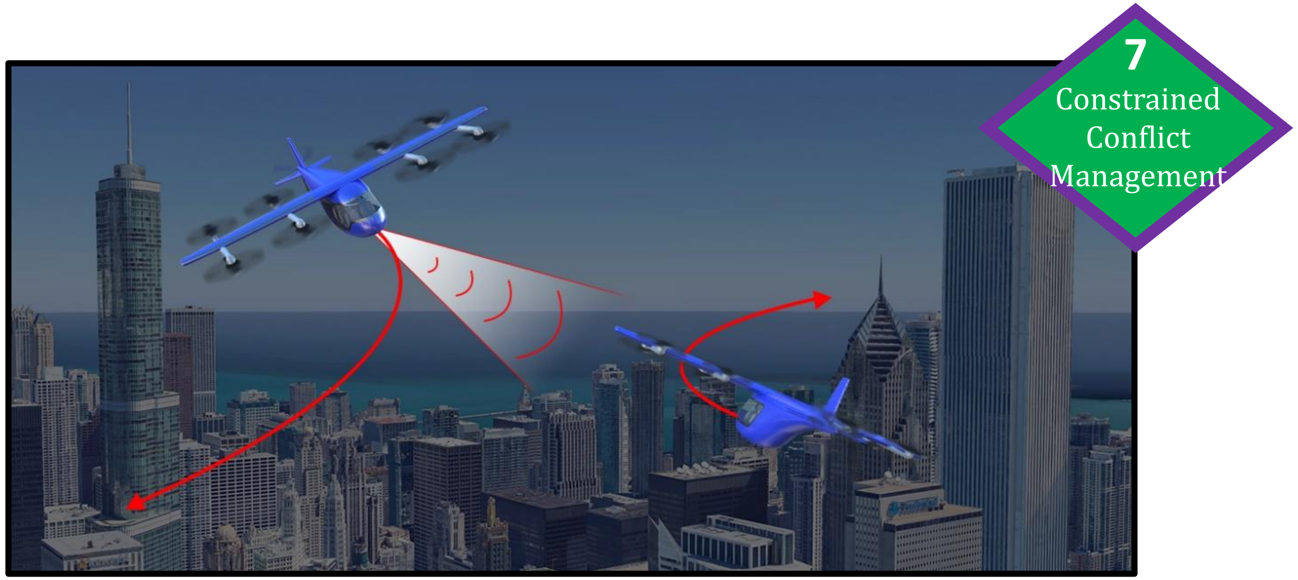
- Intra-Urban Tactical Conflict Management – Demonstrate in-flight separation assurance, collision avoidance, and appropriate airspace management information exchange (i.e., flight plan amendments) including:
  - Various geometry setups, test altitudes, aircraft sizes (general aviation, sUAS, Urban Passenger transport), cooperative and non-cooperative and speed of airborne intruders
  - Various environment backgrounds (sun, clouds, terrain clutter, etc.)
- Legacy Aircraft Tactical Conflict Management – Demonstrate interoperability with legacy aircraft (e.g. commercial, general aviation, etc), specifically when operating in terminal areas, including coordination with ATC, TCAS/ACAS interoperability, etc

IGC Airspace Functional Objectives

- Intra-Urban Tactical Conflict Management – Demonstrate in-flight separation assurance services, ability of airspace management system to support/provide traffic conflict management, provide airspace advisories, and detect secondary conflicts
- Legacy Aircraft Tactical Conflict Management – Demonstrate interoperability of UAM aircraft with legacy aircraft (e.g. commercial, general aviation, etc), specifically when operating in terminal areas, including coordination with legacy ATC, TCAS/ACAS interoperability, etc
- Scheduling - Demonstrate ability of UAM AOM system scheduling to respond to traffic conflict resolutions including negotiating route updates and STA's for all impacted aircraft

Scenario 7 – Constrained Conflict Management

Conflict management that considers simultaneous issues across the aircraft and AOM that must be solved together while considering spatial constraints (e.g., no-fly zones), temporal constraints (e.g., sequencing and scheduling), service boundaries (e.g., CNS service areas), and aircraft state of health (e.g., when aircraft is in a degraded mode). Builds upon Scenario 6, increasing complexity of operations.



IGC Aircraft Functional Objectives

- Obstacle and Aircraft Avoidance – Demonstrate ability to detect and avoid ground and air obstacles, including non-cooperative intruder aircraft intersecting intended flight path.
- Cooperation with other UAM aircraft – demonstrate ability of UAM aircraft to perform tactical collision avoidance maneuvers without triggering follow-on collision avoidance maneuvers, including when the aircraft is in a degraded state
- Cooperation with AOM service supplier – demonstrate ability to perform tactical collision avoidance without creating cascading effects to the AOM system, including when the aircraft is in a degraded state

IGC Airspace Functional Objectives

- Obstacle and Aircraft Avoidance – AOM system responds appropriately to avoid cascading failures when a aircraft depart from planned trajectories due to an obstacle/aircraft avoidance maneuver
- Cooperation with other AOM service suppliers – AOM can interoperate with other AOM service suppliers, not sending instructions to aircraft that will disrupt other AOM service supplier’s traffic management
- Cooperation with UAM aircraft – demonstrate ability to send directions to aircraft that do not create cascading impacts of tactical maneuvers from aircraft to avoid collisions, including when aircraft are in degraded states

NASA and FAA Grand Challenge Scenarios Collaboration

- The NASA Grand Challenge will highlight regulatory gaps and needs and also identify and validate UAM enablers. Data collected will help inform and shape FAA activities necessary for UAM implementation in the areas of:
  - Research plans and analysis activities in defining the UAM Ecosystem
  - UAM Operational concepts and requirements development
  - UAM Standards Development
    - Flight Safety Standards and risk assessment, Airworthiness Certification, SVO Pilot cert/Training, Operator certification, Maintenance standards, C2 Standards, DAA standards, Environmental standards, and Information Assurance
  - Development of UAM procedures
    - Air Traffic Procedures/PIC Procedures/Airport & Vertiport Procedures/Manufacturer procedures/Owner procedures/security procedures/Hazard Material procedures
  - Airspace Design constructs
    - Airspace Charting and Facility Maps
  - Systems development and integration
    - Aircraft, Aircraft sub-systems, ATM, CNS
  - Policies development
    - Air Traffic Policy/Rulemaking/waivers and exemptions/ARC's & Guidance/Environmental/Alignment with global regulatory bodies
  - Outreach and Community Engagement

Flow Down of Data Collection Requirements

- Goals and Objectives
  - FAA Standards to be updated for UAM
    - Each Standard associated UAM Elements
      - UAM Elements consist of how it is done today to compare or works with a current standards body
        - » Scenarios made up of UAM Elements
          - Method of recording data
            - o FRR Data Gathering and Report
            - o Differential GPS
            - o Two-way Fiber Network to UTM
              - o Update rates
            - o Range Safety
              - ADS-B
              - C-Band Beacon
              - Video Recording
              - Voice Recording
              - Flight Termination System (requires TM from vehicle and vehicle dynamic state data)
            - o ATI Recorded UTM/Vehicle scheduling and separation
            - o Acoustic
              - Inertial Measurement Unit
            - o Aircraft recorded Data (Motor Temp, Motor Controller Temp, Battery reserves and health)
              - Flight Termination System (requires TM from vehicle and vehicle dynamic state data)

Infrastructure

1. **Accelerate Certification and Approval.** Collect relevant data through test scenarios and mission task elements that assist the FAA in standardizing test procedures and data requirements for UAM vehicle certification, operator certification, and operational approval, including considerations for increasing levels of automation and autonomy

   - Infrastructure
     - FAA Advisory Circular, AC 150/5390-2C, Heliport Design Guide
       - UE 1 TLOF
         - » 1 Rotor Diameter square
       - UE 2 FATO
         - » 1 ½ Vehicle overall length or width which ever is greater
       - UE 3 Safety Area
         - » ¾ Vehicle overall length – ½ Rotor Diameter
       - UE 4 Parking Separation
         - » Greater than 10ft or 1/3 rotor diameter
       - UE 5 Downwash
         - » Rotor downwash loads are approximately equal to the weight of the helicopter distributed uniformly over the disk area of the rotor
       - UE 6 hover Taxi
       - 2 Rotor Diameters
         - » Scenarios 1-7 all have ground operations/taxi, takeoff and landing to get record, repeatability, maneuverability and controllability
           - DGPS, Video recording,

Vehicle Operations

2. Develop Flight Procedure Guidelines. Test different flight procedures and related airspace design constructs that enable the development of preliminary flight procedure guidelines and airspace design criteria

– Operations

– Part 91 General Operating and Flight Rules (14 CFR Part 91)

- UE 7 Obstacle Clearance
- UE 8 Vertical Flight Track
- UE 9 Ground Track
- UE 10 Calculate Critical(low) - Critical(high) - DeltaISA(low)
- UE 11 Along Track Tolerance (ATT)
- UE 12 Wind Spiral and Distance of Turn Anticipation
- UE 13 Reaction and Role (RR)/Turn Initiation Areas (TIA)
- UE 14 Final Role Out Point
- UE 15 Bias Errors
    - » Scenario 3 UAM Ports and Approaches
        - DGPS, Video, DAA, Landing Contingency

Example: **CG to Clear Obstacles – NASA Grand Challenge**