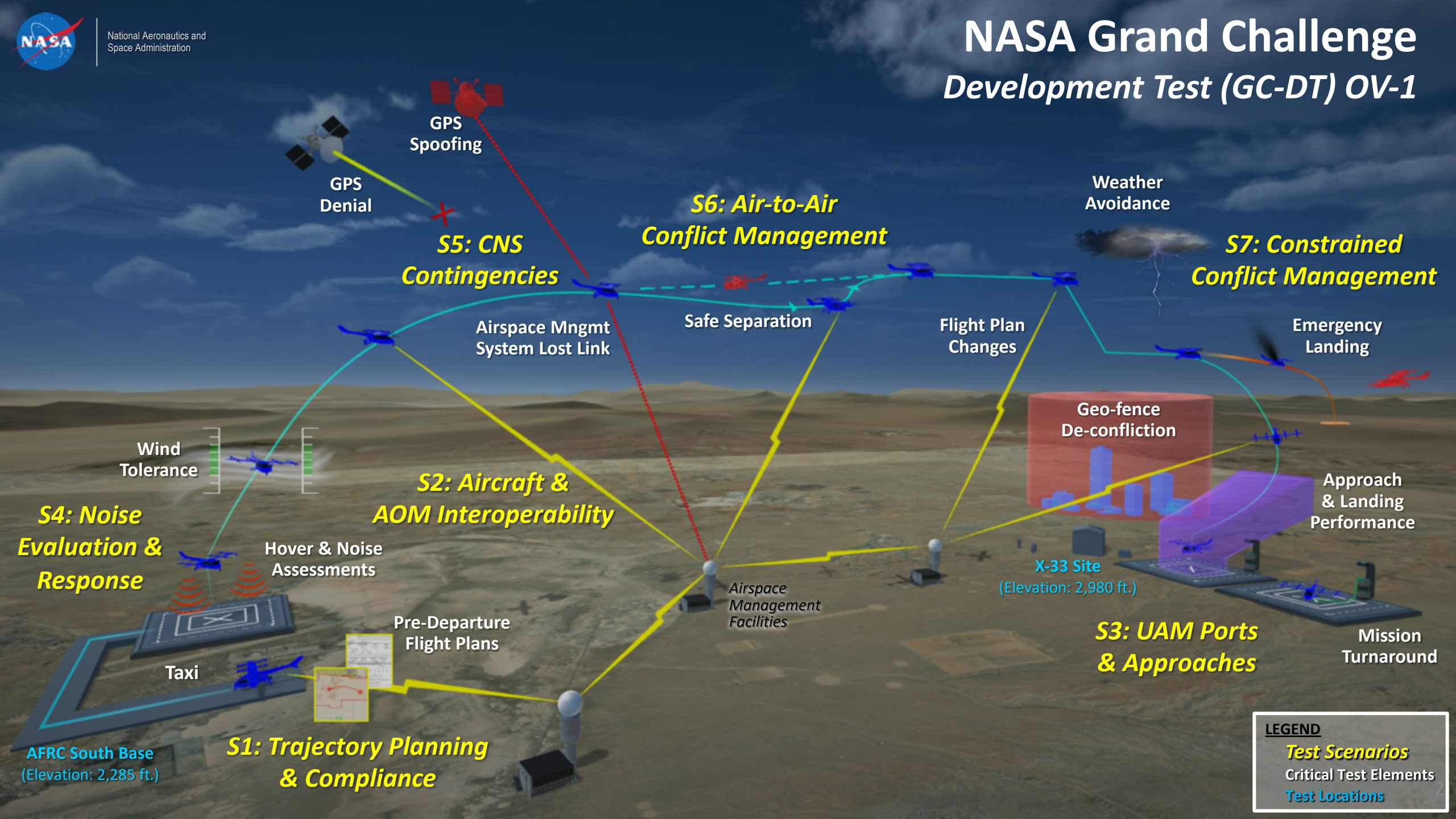
ARMD Urban Air Mobility Grand Challenge
Attachment A / Exhibit A
Grand Challenge Safety Scenarios

September 17, 2019

National Aeronautics and Space Administration

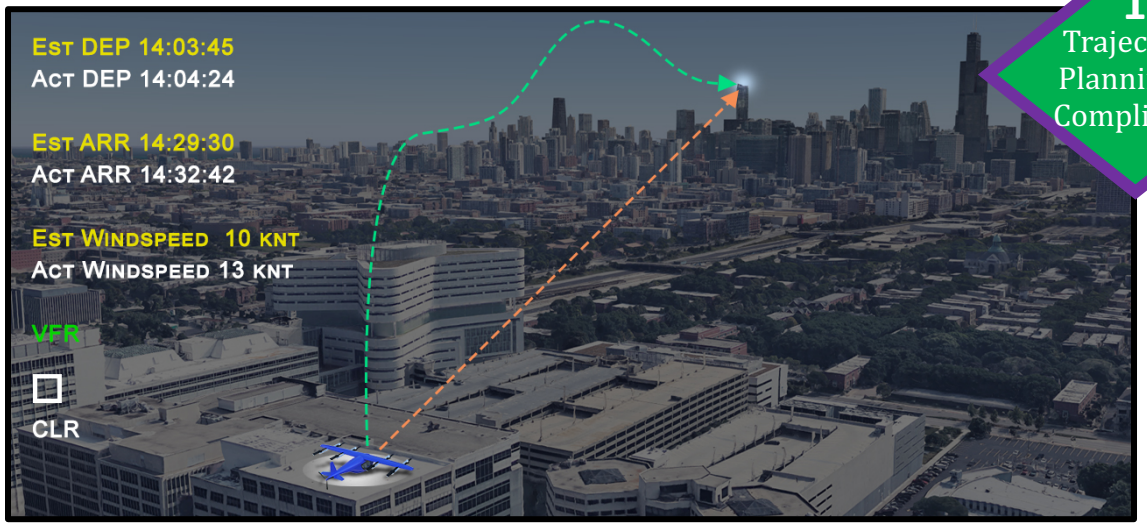
NASA Grand Challenge

Development Test (GC-DT) OV-1



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

GC Series Aircraft Functional Objectives

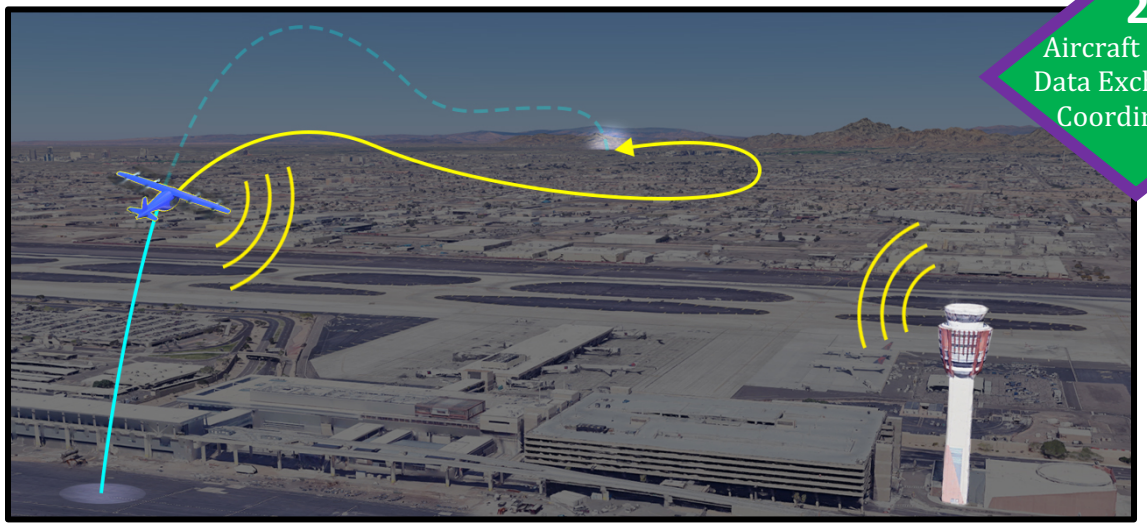
- Airspace Data Exchange – Demonstrate transmission to the ground of aircraft state, flight plan and revisions, etc. per a UTM API.
- Pre-departure Plan – Pre-departure flight plan generated, submitted and negotiated and accepted.
- Execute Flight Plan – Takeoff at pre-approved time and execute approved 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.

GC Series 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 (CNS) 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.



GC Series Aircraft Functional Objectives

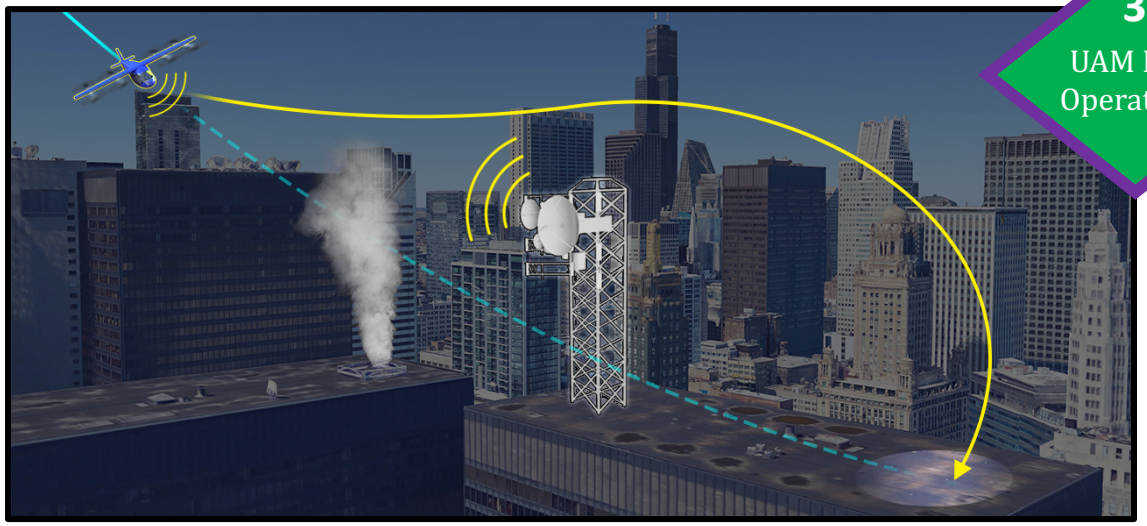
- All functional objectives from Scenario 1 apply to Scenario 2.
- Flight Plan Changes – Aircraft receives and responds to AOM system advisories for in-flight changes of planned routes, including: new scheduled time of arrival, new landing location, etc.
- Flight Plan Changes – Aircraft generates and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

GC Series 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.



GC Series 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 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.

GC Series 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.

GC Series Aircraft Functional Objectives

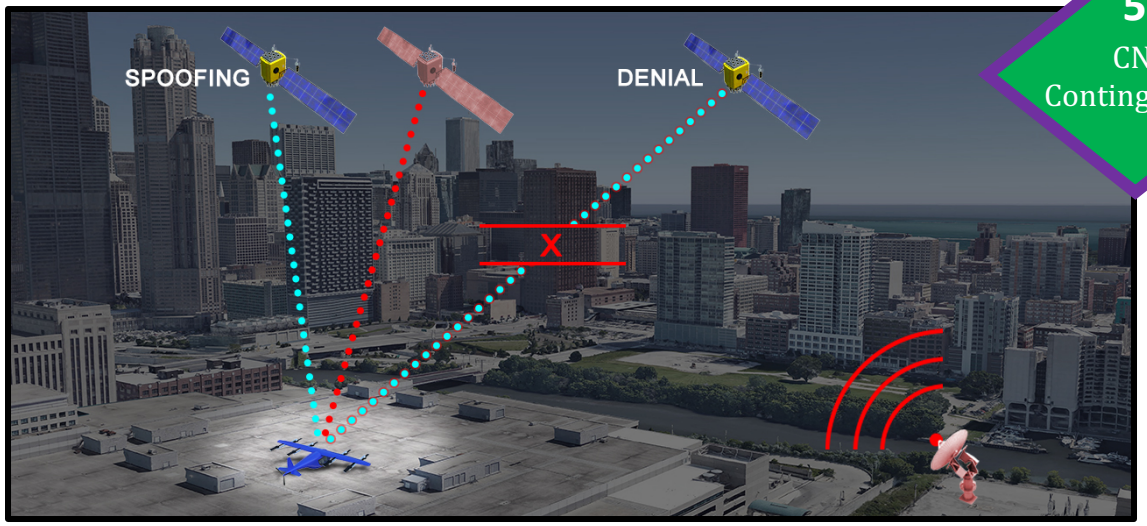
- Noise Characterization – Measure aircraft noise through standard flight conditions, maneuvers and profiles, including takeoff/landing, transition, cruise, etc. Precise and repeatable flight conditions flying over a microphone array.
- Noise Variability – Measure the effect of dynamic environmental 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 of UAM aircraft operations. Integrate local atmospheric measurements and predictions into calculations of low noise flight profiles and/or accept low noise flight profile generated by 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.

GC Series 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

GC Series Aircraft Functional Objectives

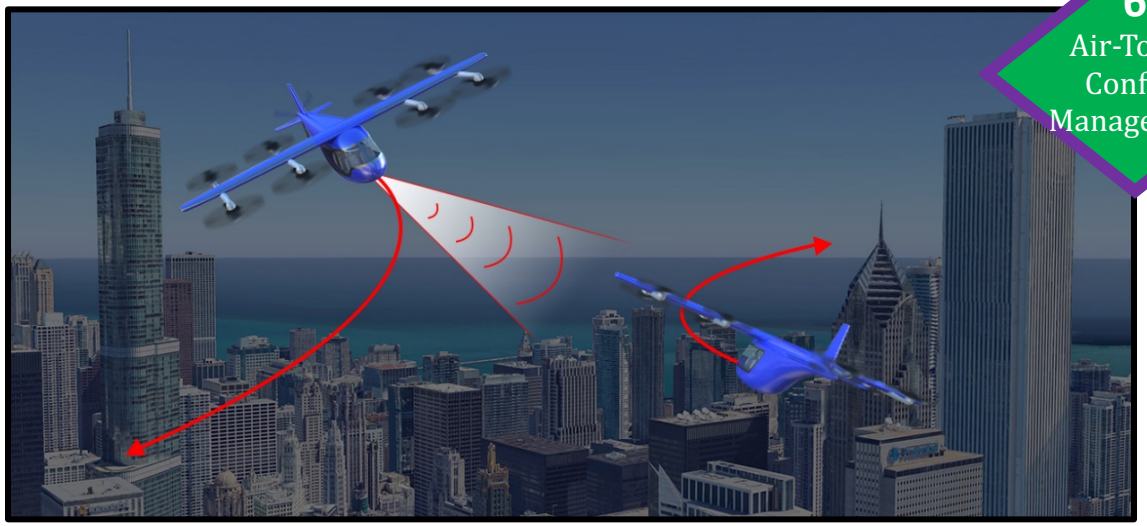
- Degraded Navigation – Evaluate system response and accuracy to primary navigation system sensor jamming/denial/degradation through a simulated loss of primary navigation system upon NASA command, requiring use backup navigation system(s) to execute response strategy.
- Aircraft Lost Link – For remotely 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.

GC Series 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, and 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 – Air-to-Air Conflict Management

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



GC Series Aircraft Functional Objectives

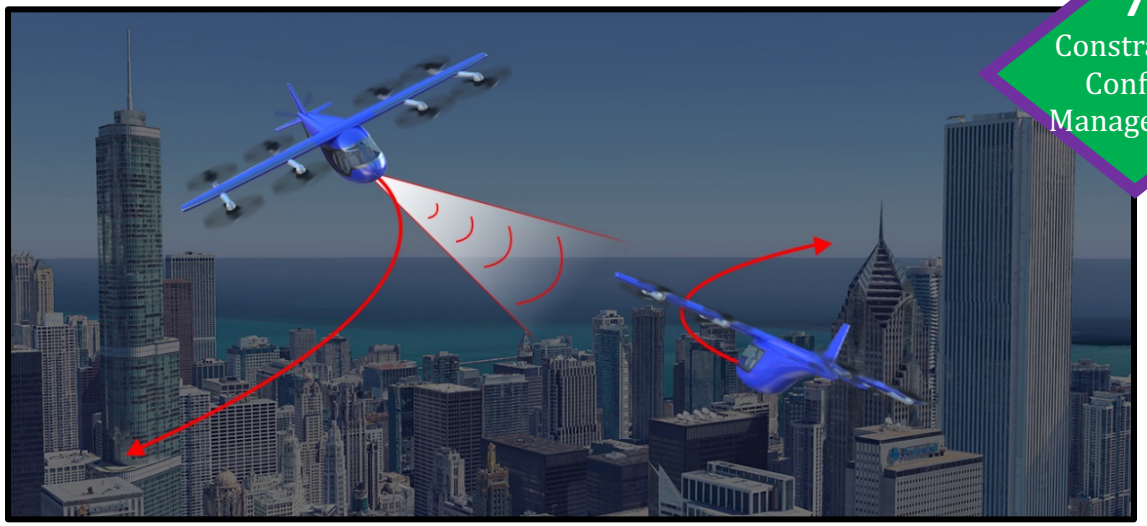
- Intra-Urban Tactical Conflict Management – Demonstrate in-flight separation assurance, collision avoidance, and appropriate airspace management information exchange (i.e., flight plan amendments) including:
  - Various geometry setups, test altitudes, aircraft sizes (general aviation, sUAS, Urban Passenger 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.

GC Series 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.



GC Series 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.

GC Series Airspace Functional Objectives

- Obstacle and Aircraft Avoidance – AOM system responds appropriately to avoid cascading failures when an 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.