



ARMD Urban Air Mobility Grand Challenge UAM Grand Challenge Scenarios

October 29, 2018

Outline

- Overview of Grand Challenge Scenarios
- GC-1 Scenarios
- GC-2 and Future Grand Challenge Scenarios
- Airspace Block Diagrams
- Mission Task Elements

UAM Grand Challenge Scenarios

The Grand Challenge consists of a series of “scenarios” that will provide participants with the ability to demonstrate the capabilities of their systems as a part of a broader, integrated UAM system. As the Grand Challenge Series progresses, these scenarios will progress in difficulty and complexity. The scenarios start with vehicle-only and airspace system-only scenarios and moving toward challenges that will require integration between vehicle and airspace systems, and are representative of UAM operations around populated areas.

Grand Challenge Scenario Goals

Provide an integrated vehicle and airspace operational environment for entrants to:

- Demonstrate airworthiness and standards for combined safety benefits & industry advancement
- Identify gaps in certification and investigate Means and Methods of Compliance to the applicable regulations
- Benchmark vehicle and airspace performance and capabilities to assess system maturity
- Identify requirements for vehicle to airspace interchange
- Demonstrate vehicle and airspace contingencies
- Integrate various simulated traffic densities and flight planning

Scenario Breakdown and Related Components

GC-1 Scenarios: The GC-1 scenarios are anticipated to provide a “proving ground” for vehicle developers to individually demonstrate the design readiness and robustness of their vehicles.

GC-2 and Future Grand Challenge Scenarios: GC-2 and future challenges in the series are anticipated to include additional scenarios to directly address the complex integrated system necessary for UAM markets to be realized.

Airspace Block Diagrams: The Grand Challenge series will involve the integration of vehicles with an airspace management system to complete the common safety and integration scenarios described in this document. The block diagrams provide a high-level functional depiction of a service-oriented integrated vehicle and airspace system for Grand Challenge.

Mission Task Elements: A set of Mission Task Elements (MTEs) are described in this document. These are draft MTE’s developed jointly by NASA and the FAA, and can be considered as some fundamental building blocks to identify the relationship between the aircraft performance and means of compliance, and to study the robustness and operational readiness of the vehicle designs.

Grand Challenge Test Scenarios

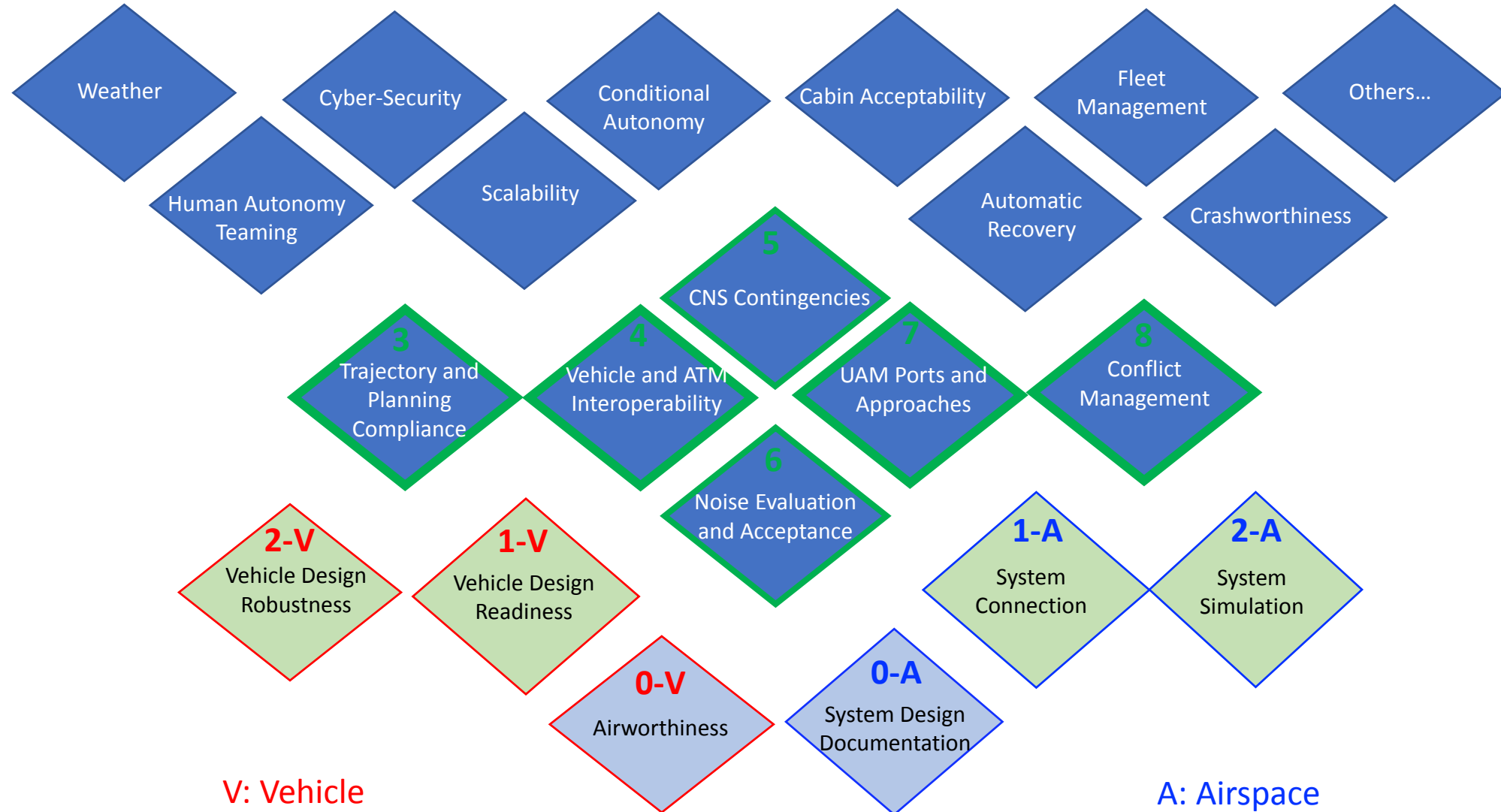
Design Readiness Reviews

A GC-2 Airspace Qualification Scenarios

V GC-1 Scenarios (Qualification at Participant Location)

GC-2 System Scenarios

GC Series Scenarios



GC-1 Scenarios

For GC-1, which is planned to be hosted in the late 2020 timeframe, vehicle participants will each be challenged to complete a series of performance characterization and safety-focused scenarios with a primary goal of helping move these vehicles toward certification. These scenarios include demonstrating the vehicle's performance and flight envelope over nominal UAM-like missions and in off-nominal situations, such as the loss of an engine or motor.

- Vehicle Scenarios:
 - Scenario 0-V: Vehicle Airworthiness
 - Scenario 1-V: Vehicle Design Readiness
 - Scenario 2-V: Vehicle Design Robustness

Scenario 0 – Vehicle Airworthiness

Airworthiness and Flight Safety Review - AFG-7900.3-001

Vehicle Airworthiness – The vehicle airworthiness review should include, where applicable, the design, fabrication, performance, and documentation of all software and hardware from the participant as well as ground and flight operational procedures. It should also include any substantiating wind tunnel, computational fluid dynamics, ground testing, simulation and flight testing that has been performed. It should also ensure that all identifiable risks have been identified, assessed, and either adequately controlled or presented to Center management as risks to be accepted in order to conduct the program.

Flight Readiness – The Flight Readiness Review Board’s purpose is to render a judgment as to whether a particular vehicle and operator have adequately considered and integrated flight safety into their proposed flight plans. Therefore, participant teams are encouraged to reveal information freely, cooperate with the review team, and be completely open in all exchanges, including those detailing any doubts or uneasiness experienced by the vehicle development and operations team.

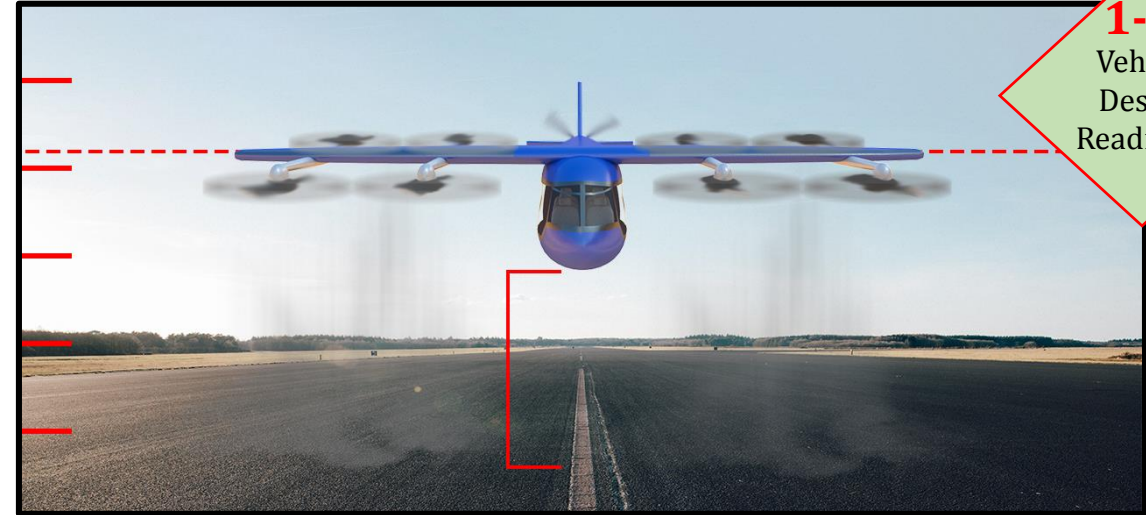


Technical Areas to be evaluated for safety (all bullets have sub-bullets in AFG-7900.3-001):

- Propulsion
- Guidance Navigation & Control
- Controls (Flight, engine, etc)
- Aerostructures
- Aerodynamics
- Flight Control Room – Flight Ops
- Maintenance
- Instrumentation
- Software
- Simulation
- FMECA
- Range Requirements
- Life Support
- Aircrew
- System Security Plan & Authorization to Operate
- Project Management

Scenario 1 – Vehicle Design Readiness

Vehicle performance and flight envelope characterization for nominal mission attributes across vehicle MTEs 1-9. Initial characterization of noise and baseline data exchanges with an airspace management system.



Vehicle - Qualification

- Demonstrate ability to execute the intent of MTEs 1 through 9 for nominal vehicle flight operations.
- Flight Characteristics – Demonstrate vehicle controllability & handling qualities (including stall recovery, in flight maneuverability, etc.), in hover, cruise and transitional flight regimes. Min weight to max weight, fore-aft CG, calm to increasing winds.
- Flight Performance – Demonstrate vehicle performance and operational flight envelope (density altitude limits, climb-rates, turn rates, wind limits, etc.) Min weight to max weight, fore-aft CG, calm to increasing winds.

GC-1 Vehicle Functional Objectives

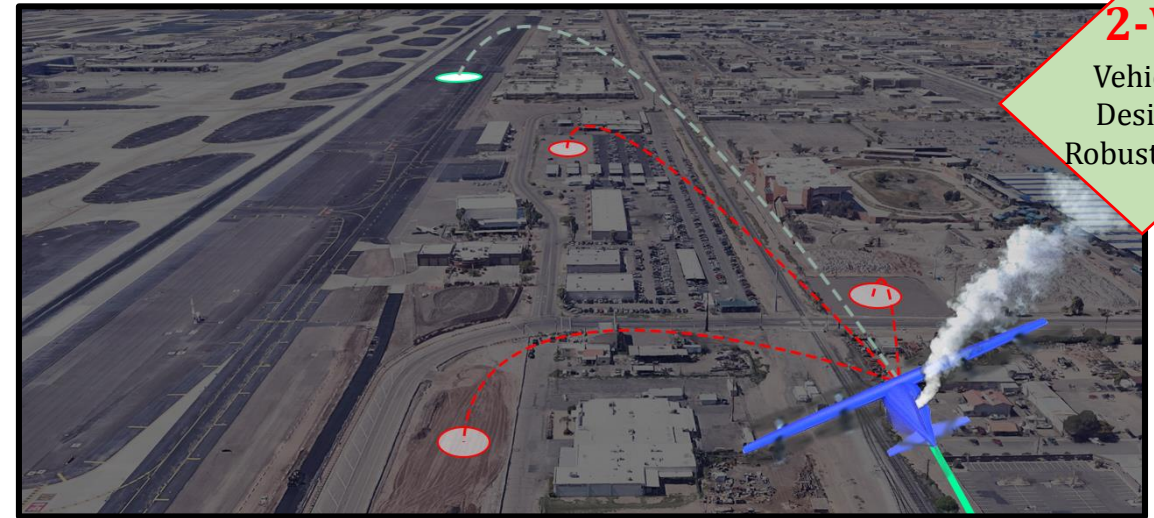
- All Azimuth Test – Demonstrate controllability in hover with wind from all azimuths to the allowable wind limits, including tailwinds.
- Trajectory planning and compliance – Demonstrate ability to generate, submit, execute and report any updates to a 4D flight plan, including dynamic environmental conditions, and landing within the pre-defined arrival time.
- Flight Performance – Demonstrate envelope and performance limits, including range, endurance, climb rate, density altitude, etc. through a variety of environmental conditions and flight profiles.
- Demonstrate turnaround time and multi-mission capabilities per MTEs 8 and 9.
- Noise – Measure noise (using multi-microphone arrays) across all flight regimes including take-off and landing, cruise, climb, descent, and during transitional flight, and performance levels. Measure noise from low noise flight profiles.
- Airspace Data Exchange – Demonstrate transmission to the ground of aircraft state, flight plan and revisions, etc. per a UTM ICD.

Scenario 2 – Vehicle Design Robustness

Demonstrate ability to safely mitigate simple vehicle failures and contingencies across MTEs 10-13, including precautionary and balked landing with and without on-board vehicle failures. Demonstrate obstacle and aircraft avoidance, and automation in situations when a pilot or operator cannot control an aircraft.

Vehicle - Qualification

- Precautionary Landing (MTE 10) – Demonstrate concept of operations to execute landing at alternative site following a simulated critical emergency, locate nearest surveyed emergency landing site, change flight path, and execute a landing at that site.
- Balked Landing (MTE 11) – Demonstrate ability to perform a balked landing, including touchdown at original landing pad.
- Failure Robustness (MTE 12, 13) – Demonstrate system robustness to degrading power, battery power reduction/fail & loss, motor/controller failures. Actually reduce power to idle on 1 motor (1 at a time, testing all motors); in forward flight and vertical mode. Failure modes informed by FMECA analysis from Scenario 0.
- Degraded Mode Performance (MTE 12, 13) – Demonstrate aircraft performance in degraded conditions. Eg. motor/engine-out glide distance, flight time vs fuel power/ battery remaining, quantify control power saturation, etc.



2-V

Vehicle
Design
Robustness

GC-1 Vehicle Functional Objectives

- Precautionary Landing – Through a variety of dynamic environmental conditions, demonstrate precautionary landing with an on-board system failure.
- Balked Landing – Demonstrate ability to perform a balked landing, including touchdown at original landing pad, through a variety of dynamic environmental conditions.
- Failure Robustness – Demonstrate envelope and performance limits following on-board failures, including range, endurance, climb rate, density altitude, etc. through a variety of environmental conditions and flight profiles.
- Automation – Demonstrate automatic vehicle control and reconfiguration in response to on-board vehicle contingencies and failures, including inability of pilot/operator to control aircraft. Ie. Pilot incapacitation, lost link, etc.
- Obstacle and Aircraft Avoidance – Demonstrate ability to detect and avoid ground and air obstacles, including non-cooperative intruder vehicles intersecting intended flight path.

GC-2 Scenarios

Following GC-1 by approximately one year, a second challenge, GC-2, is planned to challenge both vehicle and airspace participants to complete a series of common safety and integration scenarios. These scenarios are designed to represent real-world UAM operations and barriers necessary for certification and operational approval.

For Grand Challenges beyond GC-1 and GC-2, it would be anticipated that vehicle and airspace participants will each be challenged to complete a series of more complex scenarios that build upon previous scenarios, focus on increased technological capabilities, and increased ability to operate in real NAS and urban operating environments.

- Airspace Qualification Scenarios
 - Scenario 0-A: System Design Documentation
 - Scenario 1-A: System Connection
 - Scenario 2-A: System Simulation
- Integrated Vehicle/Airspace Scenarios:
 - Scenario 3: Trajectory Planning & Conformance
 - Scenario 4: Vehicle & ATM Interoperability
 - Scenario 5: CNS Denied Environment
 - Scenario 6: Noise & Community Acceptance
 - Scenario 7: UAM Ports & Approaches
 - Scenario 8: Conflict Management

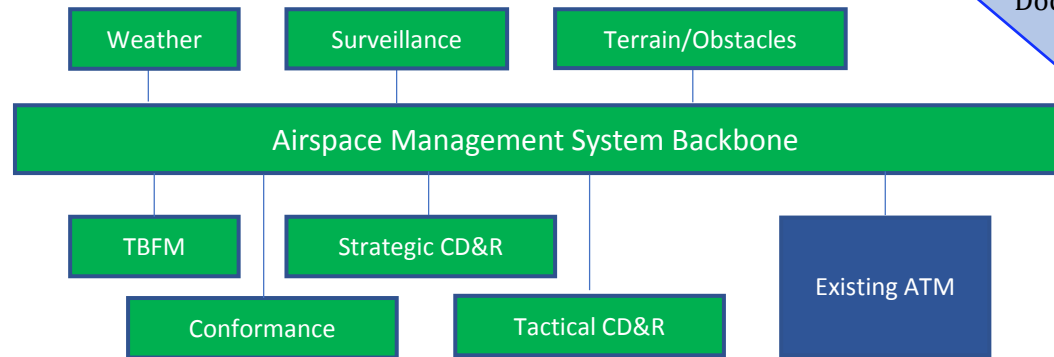
Scenario 0 – System Design Documentation

Evaluate the airspace assumptions and system design documentation provided by industry partners. System design is expected to be based on a UTM-like service oriented architecture and interface.

System Design Documentation Qualification

- Provide documentation of airspace system functionality including:
 - Definition of airspace system assumptions
 - Airspace design description
 - System requirements, including external connection requirements
 - Data requirements and data management plan
 - System design review presentation
 - Configuration Management Plan, including security plan
 - Network diagram
- Provide documentation of compliance to NASA provided ICD with a UTM-like system.
- Provide IT security documentation to install software/hardware onto TestBed simulation laboratory network (if necessary based on system design)

0-A System Design Documentation



System Design Documentation Criteria

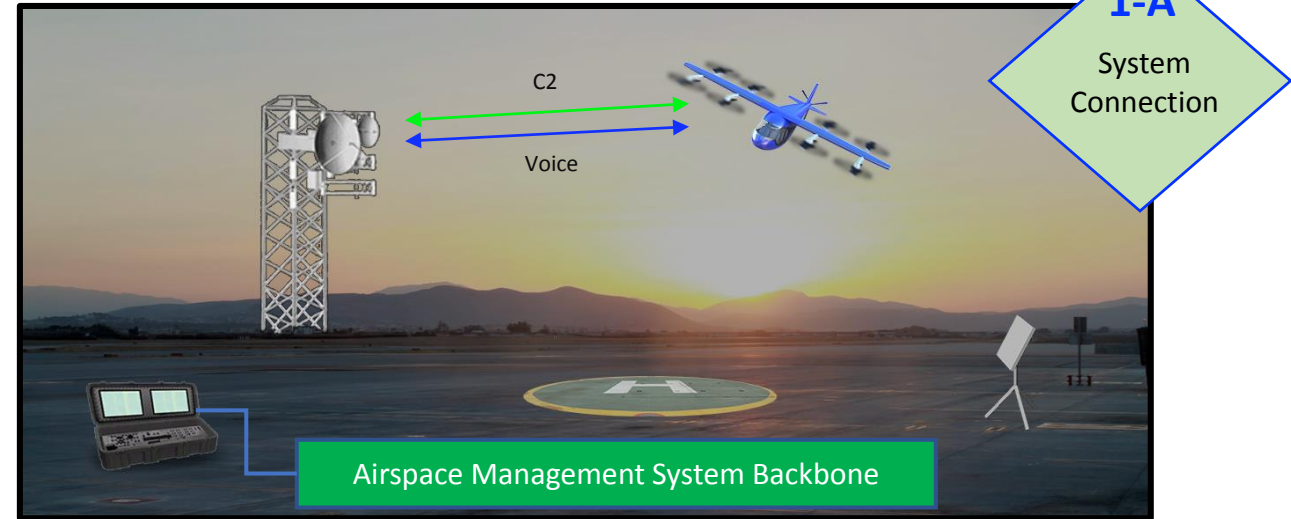
- Document a UAM airspace system consistent with operational assumptions
- Document system components and system functionality
- Provide output logs demonstrating compliance with NASA provided ICD
- Sign an Interconnection Security Agreement (ISA), or similar, for connecting system to test range

Scenario 1 – System Connection

Verify airspace system integration through ingestion of live (or pre-recorded from live) vehicle and range data (surveillance, weather, etc.).

System Connection Qualification

- Capability of connecting with NASA provided UTM-like airspace system, if applicable
- Capability of receiving of supporting data, e.g., pre-recorded vehicle track data, winds/weather data
- Capability of responding to received data as described in the function documentation



System Connection Success Criteria

- Demonstrate the capability of connecting with NASA provided UTM-like ICD, if applicable
- Demonstrate the capability of ingestion of supporting data, e.g., pre-recorded vehicle track data, winds/weather data
- Demonstrate the capability of appropriately respond to ingested data as described
- Identification of additional critical aircraft information necessary to support initial integrated vehicle and airspace scenarios

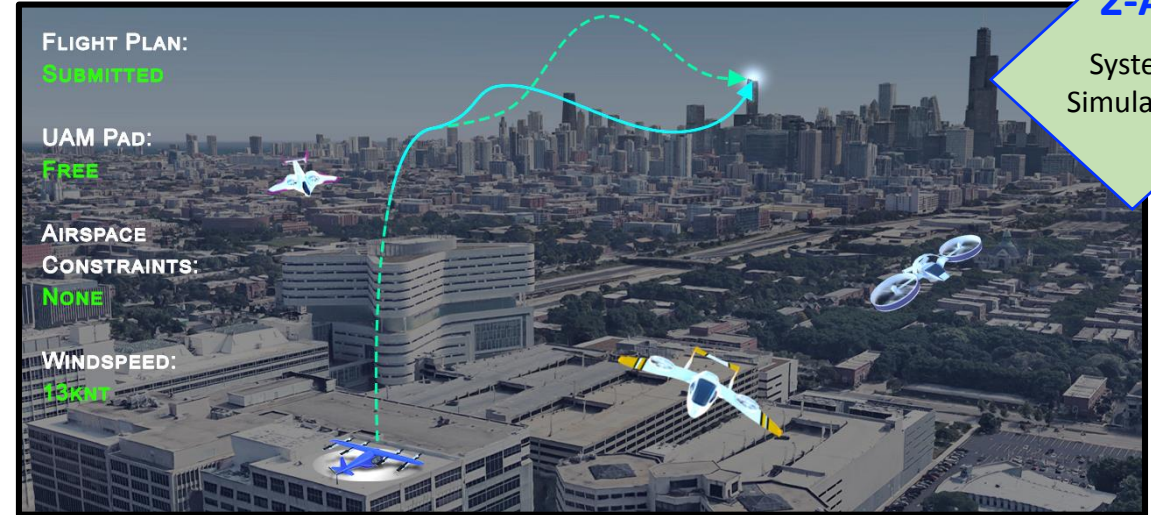
Scenario 2 – System Simulation

Demonstrate and validate functionality of the airspace system and components in simulation.

System Simulation Qualifications:

Demonstration the following capabilities:

- Pre-departure flight plan submission, negotiation, deconfliction, including: airspace constraints, flight plan deconflict, vertiport information.
- Vehicle trajectory tracking and conformance monitoring
- Evaluation of laterals, altitude and time variations from intended 4-D route plan, in dynamic environmental conditions
- Demonstrate in-flight safety alerts and messaging including vertiport status, airspace constraints

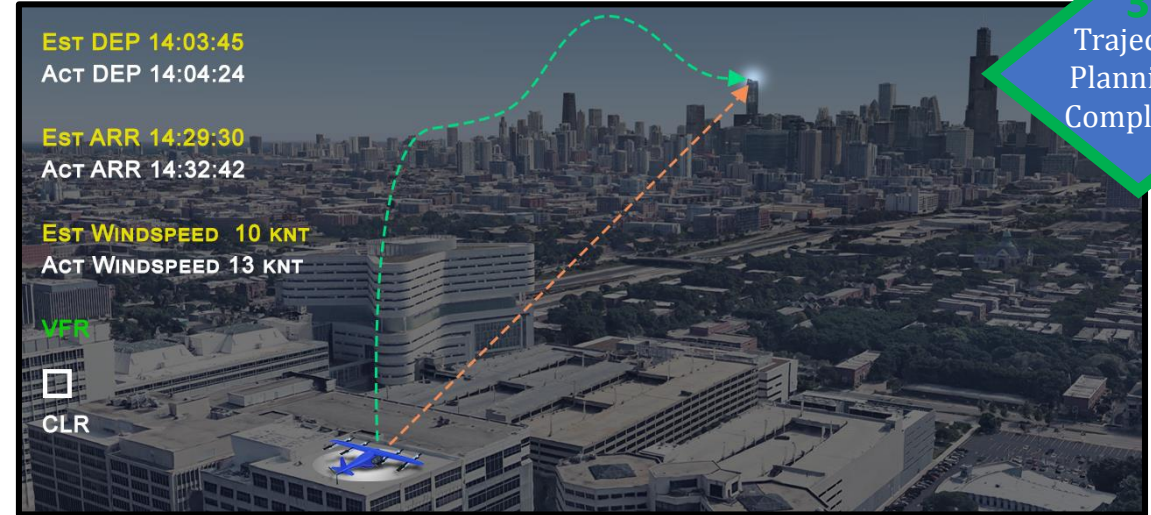


System Simulation Success Criteria

- Demonstrate a UAM airspace system using pre-recorded/simulated data
- Demonstrate virtual flight simulators “fly” vehicles appropriately over their operational envelope
- Demonstrate contingency plan safety critical system failures (e.g., CD&R)
- Document redundancy requirements
- Demonstrate the capability of safe operations in situation like sporadic/dynamic blocked airspace on flight route, crosswind check, UAM pad not free/Alternate landing site (very low density operations)

Scenario 3 – Trajectory Planning & Compliance

Flight planning that accommodates ATM and vehicle constraints, and precision of vehicle trajectory conformance to the flight plan across MTE 2-7 and a range of density altitudes. Evaluate format for exchange of trajectory information between vehicle and airspace management systems.



3
Trajectory
Planning &
Compliance

GC-2 Vehicle Functional Objectives

- Pre-departure Plan – Pre-departure flight plan generated, submitted and negotiated.
- 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.
- 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 airspace and scheduling constraints under uncertain (real-world) flight conditions.
- Turnaround Time – Demonstrate turnaround time and multi-mission capabilities.

GC-2 Airspace Functional Objectives

- Pre-departure Plan – Pre-departure flight plan negotiation with vehicle 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.
- Airspace Scheduling – Examine effects of aircraft trajectory variability on scheduling, rerouting functions and landing (in shadow mode).

Scenario 4 – Vehicle & ATM Interoperability

In-flight re-planning, negotiation and execution that accommodates ATM and vehicle constraints, and responds to real-world uncertainties. Exercise exchange of trajectory information, ATM and vehicle constraints, and user preferences between vehicle and airspace management systems.



GC-2 Vehicle Functional Objectives

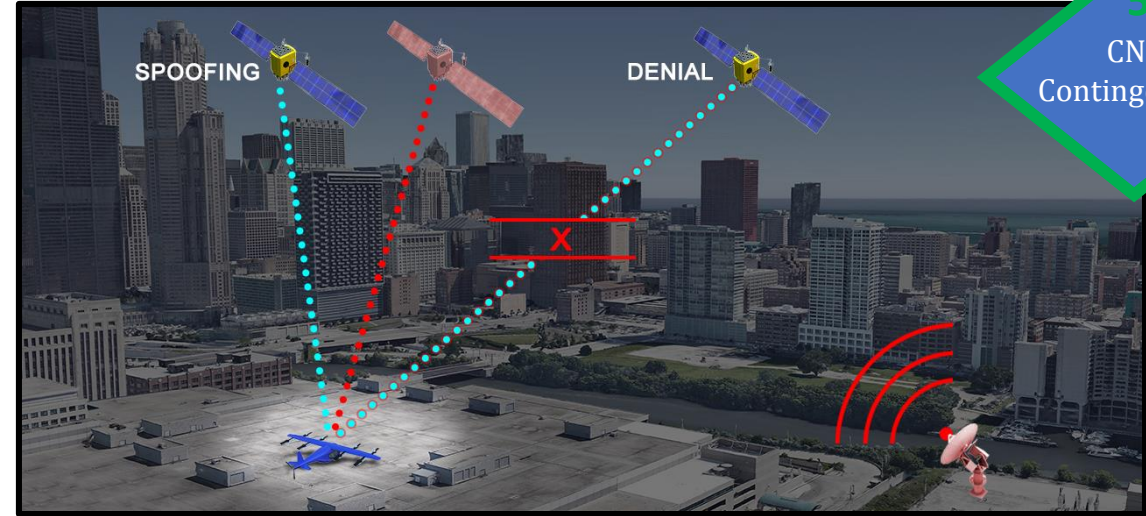
- All functional objectives from Scenario 3 apply to Scenario 4.
- Flight Plan Changes – Vehicle receives and responds to ATM advisories for in-flight changes of planned routes, including: new scheduled time of arrival, new landing location, etc.
- Flight Plan Changes – Vehicle generates and requests in-flight trajectory changes and negotiates with ATM system.
- Interoperability – Evaluate airspace and vehicle system interactions with communications and negotiations.
- Flight Path Changes – MTE 5 flight path performance will be evaluated, including energy reserves.

GC-2 Airspace Functional Objectives

- All functional objectives from Scenario 3 apply to Scenario 4.
- Flight Plan Changes – UAM ATM generates, sends and negotiates updated advisories to the vehicle in-flight. Eg. New scheduled time of arrival, new landing location, conflict management, new routing, etc.
- Flight Path Changes – ATM receives and responds to in-flight trajectory changes from the vehicle.
- Interoperability – Evaluate airspace and vehicle system interactions with communications and negotiations.
- Flight Path Changes – Trajectory conformance to the negotiated clearance will be evaluated.

Scenario 5 – CNS Contingencies

Identification, mitigation and response to contingencies related to degradation/loss of primary vehicle navigation, vehicle and airspace communications, and/or airspace surveillance. Exercise ConOps that incorporate robust, reliable and fault tolerant CNS system.



GC-2 Vehicle 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.
- Vehicle Lost Link – For remotely piloted vehicles, loss of vehicle communication / control from the ground station. Demonstrate ability to recover from loss of communications.
- Airspace Lost Link – For all vehicles, loss of communications between vehicle and airspace systems. Demonstrate vehicle and mission procedures for loss of communications.
- Airspace Interoperability – Appropriate coordination with airspace management system in response to CNS contingency situations.
- Automation – Demonstrate automatic vehicle control and procedures in response to CNS contingency situations.

GC-2 Airspace Functional Objectives

- Degraded Navigation – Evaluate airspace system response to loss of precision navigation of as single or multiple vehicles following a loss of their primary navigation system.
- Vehicle Lost Link – Evaluate airspace redundancy plan based on ConOps for loss of communications with one or more vehicles, accommodation of non-conforming vehicles, real-time response to vehicles that do not follow current instructions.
- Degraded Surveillance – Evaluate airspace system response and mitigation procedures to loss of surveillance of vehicles in small or large areas of operations.
- Vehicle Interoperability – Appropriate coordination with vehicle and the ATM in response to CNS contingency situations.

Scenario 6 – Noise Evaluation and Acceptance

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

GC-2 Vehicle Functional Objectives

- Noise Characterization – Measure vehicle noise through standard flight conditions, maneuvers and profiles, including takeoff/landing, transition, cruise, etc. Precise and repeatable flight conditions flying over an microphone array.
- Noise Variability – Measure the effect of dynamic environmental conditions (winds, turbulence, altitude, etc.) on the noise produced by UAM vehicles.
- 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 vehicle operations. Integrate local atmospheric measurements and predictions into the calculation of low noise flight profiles.
- Community Acceptance – Assess community acceptance of noise exposure from UAM vehicles using the noise measurements for the vehicles included in the Grand Challenge.

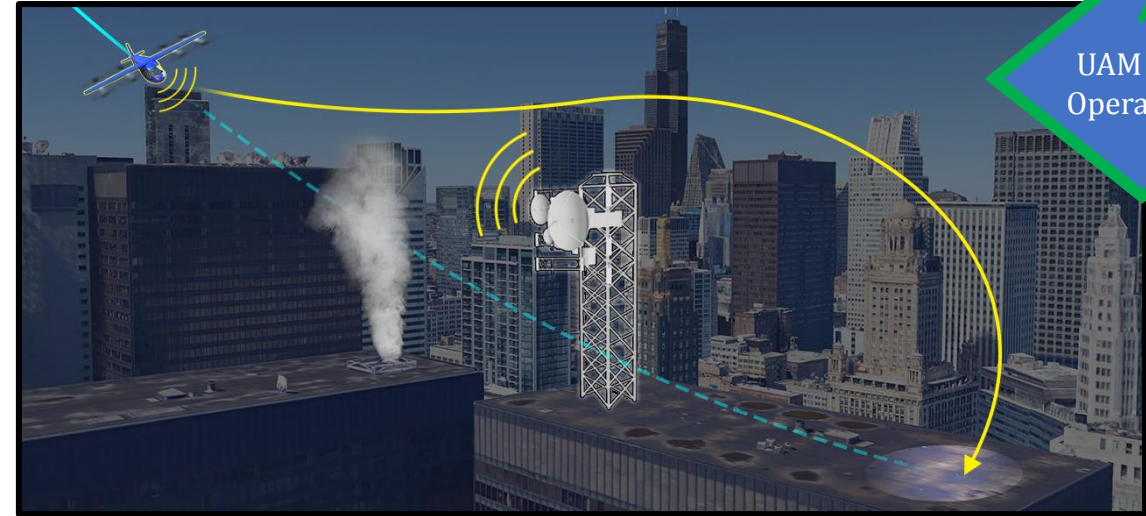


GC-2 Airspace Functional Objectives

- 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.
- 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-vehicle flight plan prediction and management to minimize the fleet noise impact in areas of UAM vehicle operations.

Scenario 7 – 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, and localized weather information,



GC-2 Vehicle Functional Objectives

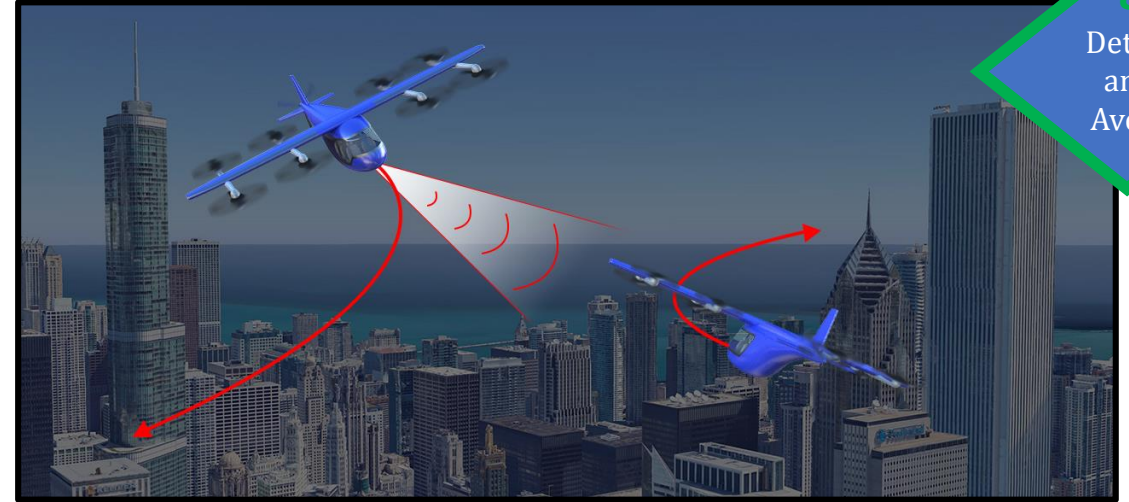
- UAM Port Procedures - Demonstrate UAM Port Procedures that include approach, landing, surface operations, take-off, departure, Actual Navigation Performance (ANP) / Required Navigation Performance (RNP), sequencing, holding patterns, operations at closely spaced UAM ports and pads, and stationary obstacles (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, vehicle 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

GC-2 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 vehicle 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 vehicles.

Scenario 8 – Detect and Avoid

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



8

Detect
and
Avoid

GC-2 Vehicle 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
- Terrain and other obstacles – Demonstrate ability to perform conflict resolution maneuvers with awareness to surrounding obstacles and terrain

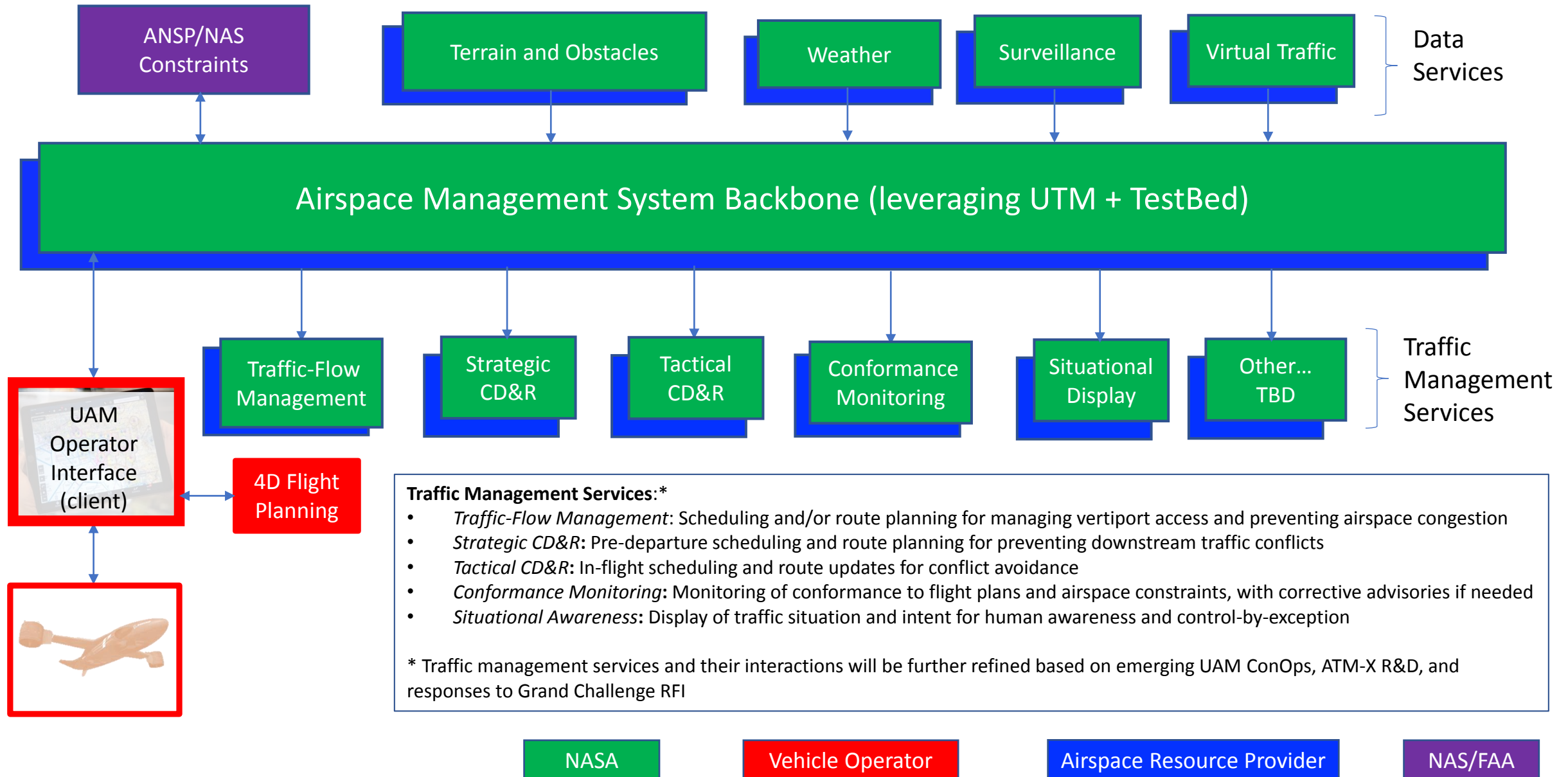
GC-2 Airspace Functional Objectives

- 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
- Terrain and other obstacles – Demonstrate ability to generate conflict resolution advisories providing awareness of surrounding obstacles and terrain
- Scheduling - Demonstrate ability of UAM airspace management system scheduling to respond to traffic conflict resolutions including negotiating route updates and STA's for all impacted aircraft

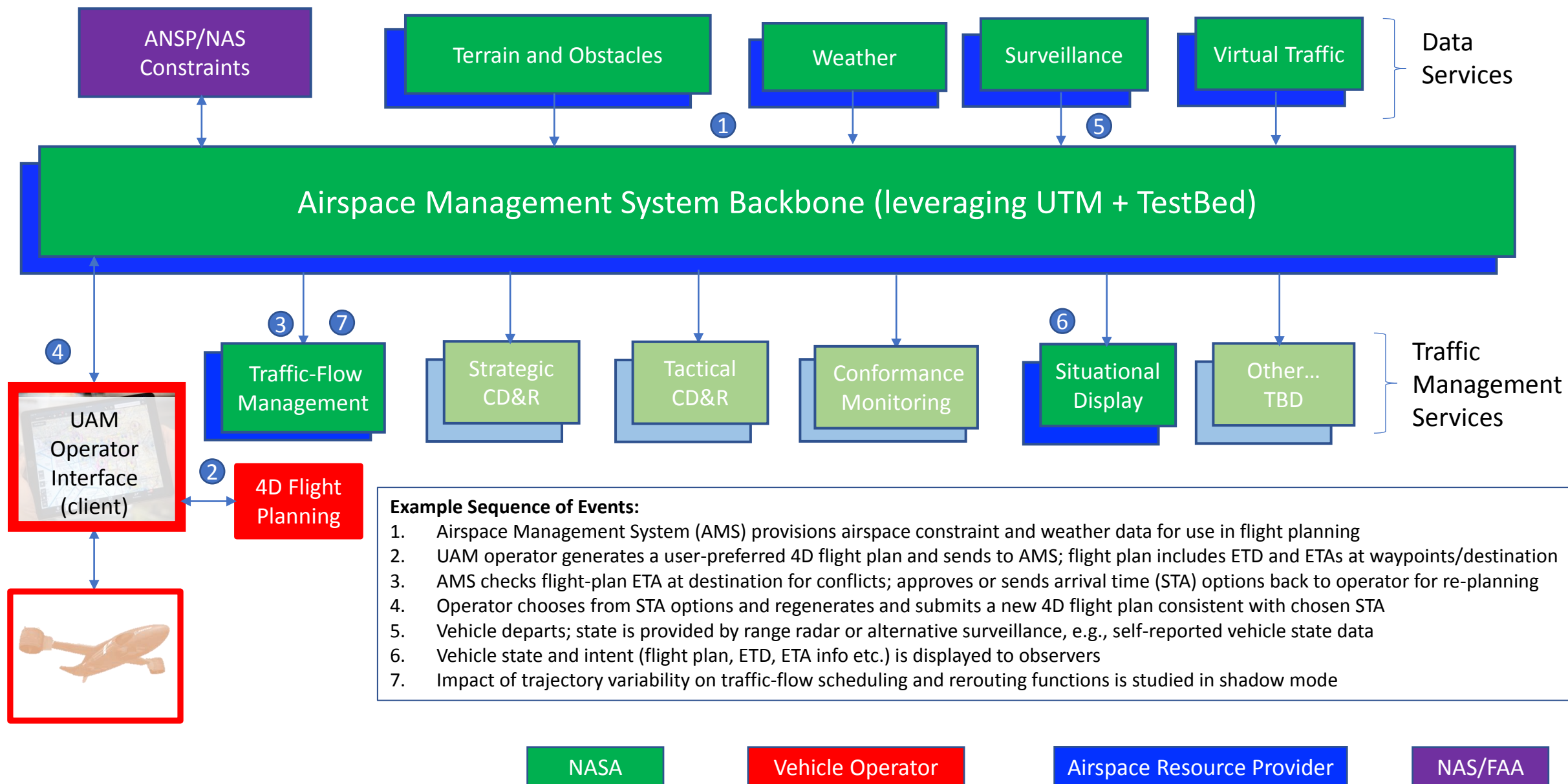
Airspace Block Diagrams

The Grand Challenge series will involve the integration of vehicles with an airspace management system to complete the common safety and integration scenarios described in this document. The block diagrams provide a high-level functional depiction of a service-oriented integrated vehicle and airspace system for Grand Challenge.

General Airspace Management System for GC Series



Airspace Management System for GC-2 Scenario 3



Mission Task Elements

A set of Mission Task Elements (MTEs) is described in this document. These can be considered as fundamental building blocks to identify the relationship between aircraft performance and flight characteristics and means of demonstrating compliance, and evaluating the robustness and operational readiness of vehicle designs. Developed jointly by NASA and the FAA, these MTEs are designed as discrete tests that challenge applicants with the goal of shedding light on operational characteristics and challenges that will help inform future certification standards and operational procedures.

This limited set of MTEs is developmental and does not represent current FAA requirements or standards for UAM vehicles.

- MTE 1 – All Azimuth capability
- MTE 2 – Taxi
- MTE 3 – Takeoff Performance
- MTE 4 – Level Flight
- MTE 5 – Flight Path Changes
- MTE 6 – Approach/Landing
- MTE 7 – Landing – Quick Refuel (charge) – Takeoff

- MTE 8 – Energy Storage, Battery Capacity
- MTE 9 – Function & Reliability Demonstration
- MTE 10 – Precautionary Landing
- MTE 11 – Balked Landing
- MTE 12 – Takeoff Failure Case
- MTE 13 – Approach/Landing Failure Case

Mission Task Elements (MTEs)

- Maneuvers for each scenario have **Mission Task Elements**. As mentioned previously, these MTEs have been developed in collaboration with the FAA to identify the relationship between the aircraft performance and means of compliance, and to study the robustness and operational readiness of the vehicle designs. These MTEs are also representative of maneuvers that would be expected to be used during vehicle certification.
- This limited set of Mission Task Elements is not intended to represent the entire spectrum of operational usage that is expected with UAM missions. However, it is considered to include some of the fundamental building blocks that can be used to challenge potential entrants to this emerging aviation industry.
- The MTEs themselves, as well as the **Required Performance** and **Desired Performance** metrics listed, do have some relation to existing certification standards for airplanes and/or rotorcraft and public use heliports and/or airports and airmen certification standards. However these MTEs are developmental and don't represent any current FAA requirements or standards for UAM vehicles.
- If a challenge participant is not able to meet the required thresholds of an individual MTE, it does not limit their ability to participate in Grand Challenge scenarios that are independent of that MTE.

MTE – Ground Handling, Taxi & Takeoff

1. **All Azimuth Capability** – Evaluate controllability in hover with wind from all azimuths to the allowable wind limits, including tailwinds

Required Performance – Assure all azimuth controllability with 5 knots wind

Desired Performance – Assure all azimuth controllability with 17 knots wind

Notes: All azimuth testing is performed in steady wind, with wind speed measured using an anemometer or other suitable method. Independent aircraft speed measurements will need to be verified.

2. **Taxi** – Vehicle must demonstrate ability to taxi (via wheel- or hover-) over a 3 mile route making 3 >90 degree turns in the same (critical) direction during the taxi. Vehicle must make 1 “full stop” (ground speed = 0) during the Taxi task. They then must make a final turn to a “line up and wait” at point B (intent is that winds at all azimuths, and turns have been experienced during the taxi)

Required Performance – Perform task with at least 5 knots wind

Desired Performance – Perform task with at least 17 knots wind

Notes: If vehicles require ground equipment to perform this task (tugs etc.) their concept of operations for achieving this MTE will need to be described.

3. **Takeoff Performance** – Takeoff performance flight test (Nominal case)

Required Performance – With winds of at least 5 knots, Vehicle must demonstrate ability to liftoff into hover, change heading of 180 degrees while position-keeping (all portions of the vehicle must remain within the heliport Safety Area). Vehicle must then climb to 1000 feet while transitioning to cruise configuration. Minimum climb gradient of 25:1 must be achieved throughout the Takeoff.

Desired Performance – With winds of at least 17 knots, Vehicle must demonstrate ability to liftoff into hover, change heading of 180 degrees while position-keeping (all portions of the vehicle must remain within the heliport Final Approach and Takeoff Area (FATO)). Vehicle must then climb to 1000 feet AGL while transitioning to cruise configuration. Minimum climb gradient of 8:1 must be achieved throughout the Takeoff.

MTE - Cruise

4. Level Flight – Evaluate ability to:

- Transition from Takeoff to Cruise flight;
- Accelerate to maximum level flight speed, hold Altitude;
- Decelerate to minimum level flight speed, hold Altitude

Required Performance

- From best rate of climb, V_Y , in the cruise configuration, vehicle must level off and capture desired altitude/airspeed within ± 100 feet/ ± 10 knots
- Demonstrate ability to perform level accel from V_Y to maximum level flight speed, V_H . Maintain altitude within ± 100 feet
- Demonstrate ability to perform level decel from V_H to V_Y . Maintain altitude within ± 100 feet

Desired Performance

- From best rate of climb, V_Y , in the cruise configuration, vehicle must level off and capture desired altitude/airspeed within ± 50 feet/ ± 5 knots
- Demonstrate ability to perform level accel from V_Y to maximum level flight speed, V_H . Maintain altitude within ± 50 feet. if applicable for control system - From trim, a push force must be required to hold altitude while accelerating
- Demonstrate ability to perform level decel from V_H to V_Y . Maintain altitude within ± 50 feet. if applicable for control system - From trim, a pull force must be required to hold altitude while decelerating

5. Flight Path Changes – Demonstrate minimum maneuver capabilities:

- Steep turns – at $V_H - 10$ knots, demonstrate ability to perform a $\sim 2g$, level turn in both directions
- Pull Up – at V_H demonstrate ability to perform a $\sim 2g$ pull up, then capture best angle of climb airspeed, V_X
- Pushover – at V_H demonstrate ability to perform a $0g$ push over, then capture maximum operating airspeed, V_{MO}

Required Performance

- Maintain entry altitude ± 100 feet, airspeed ± 10 knots, bank angle, Φ , ± 5 degrees
- Obtain target airspeed, V_X , $+10, -0$ knots
- Obtain target airspeed, V_{MO} , $+0, -10$ knots

Desired Performance

- Maintain entry altitude ± 50 feet, airspeed ± 5 knots, bank angle, Φ , ± 5 degrees
- Obtain target airspeed, V_X , $+5, -0$ knots
- Obtain target airspeed, V_{MO} , $+0, -5$ knots

Notes: The vehicle should not exhibit a tendency for oscillatory behavior that interferes with the ability to perform the MTE.

MTE – Landing and Turnaround

6. **Approach/Landing** – nominal demonstrated in flight
Required Performance – With crosswinds of at least 5 knots at the landing site, Vehicle must demonstrate ability to transition from cruise flight to landing configuration and fly an 8:1 approach and make a landing at a surveyed landing site.
Desired Performance – With crosswinds of at least 17 knots at the landing site, Vehicle must demonstrate ability to transition from cruise flight to landing configuration and fly an 8:1 approach and make a landing at a surveyed landing site. Vehicle must stop within the TLOF.
7. **Landing – Quick Refuel (charge) – Takeoff** – Demonstrate ability to execute a nominal landing, complete a quick recharge/refuel and then perform a nominal takeoff in the opposite direction
Required Performance – N/A
Desired Performance – Recharge/Refuel from less than 50% of battery/fuel capacity to full capacity in <30 minutes
8. **Energy Storage, Battery Capacity** – Demonstrate sensitivities of energy storage and related vehicle performance (range, endurance, etc.) to variations in flight path, flight aggressiveness, climb/descent angles/rates, altitudes, temperatures, etc. Reserves are measured after every flight. Some of this would be performed as part of the airworthiness, envelope expansion, basic performance measurements. MTE will help to assess the operational readiness of the vehicle.
Required Performance – Balked Landing with 2NM alternate landing location
Desired Performance – 20 minutes plus balked landing with 2NM alternate landing location
9. **Function & Reliability Demonstration** – Demonstrate ability to complete multiple back-to-back flight cycles in a simulated operational mission environment.
Required Performance – Complete 1 cycle with a total point to point distance of 20 NM consisting of a nominal takeoff, climb at V_Y to 6000 feet Pressure Altitude, accelerate to V_H , cruise for 20 NM, transition, perform an 8:1 approach and landing to a full stop.
Desired Performance – Complete 4 back-to-back point A to point B flight cycles including 1 Taxi MTE, multiple crosswind takeoffs and landings, and performing all MTEs with the exception of the Precautionary and Balked Landing MTEs.

MTE – Contingency Landing

10. Precautionary Landing – Demonstrate ability to respond to a simulated critical emergency, locate nearest surveyed emergency landing site, change flight path, and execute a landing at that site.

Required Performance – Outside of a 5000 foot radius around the intended landing area, avoid any obstacle by 200 feet vertical, and 100 feet lateral, make nominal landing at nearest surveyed landing site. Do not descend below 200 feet AGL (referenced to surveyed emergency landing site) at any point during the final approach. Do not descend below the 25:1 surface around the Final Approach and Takeoff Area (FATO) at the emergency landing site, touchdown within the FATO.

Desired Performance – Same as above, but do not descend below a 8:1 surface centered around the emergency landing site, touchdown within the Touchdown and Liftoff area (TLOF).

11. Balked Landing – After transit from point A to planned arrival point B, make an 8:1 approach to 100 feet above the surveyed landing site, execute balked landing, climb out and land at surveyed alternate landing site (at least 2 NM from intended landing site) and execute a safe landing. Verify fuel/battery time remaining estimations provide accurate and usable information for the pilot/operator in determining they have adequate reserve energy available.

Notes: The required/desired performance parameters here are likely driven by Weight, Altitude & Temperature (WAT) requirements.

MTE – Flight Critical System Failure

12. Takeoff Failure Case

Required Performance – After any expected failure, or combination of failures, vehicle must be capable of survivable descent and touchdown (not required to be a surveyed landing vertiport).

Desired Performance – After any expected failure, or combination of failures, vehicle must be capable of either:

- a. controlled flyaway with a minimum climb rate of 100 feet per minute and 8:1 climb gradient, then ability to perform a landing at an alternate surveyed landing vertiport
- b. ability to safely return to the takeoff point without descending below the 25:1 surface around the FATO

13. Approach/Landing Failure Case

Required Performance – After any expected failure, or combination of failures, vehicle must be capable of survivable descent and touchdown (not required to be a surveyed landing vertiport).

Desired Performance – With crosswinds of at least 17 knots at the landing site, and after any expected failure, or combination of failures at the critical time during transition or approach, vehicle must demonstrate capability of completing the 8:1 approach and landing at the planned landing site. Vehicle must stop within the FATO.