



Advanced Air Mobility National Campaign

Starr Ginn - NC Lead, David Zahn - Airspace Principal Investigator



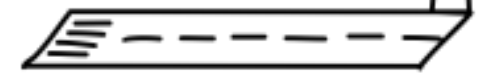
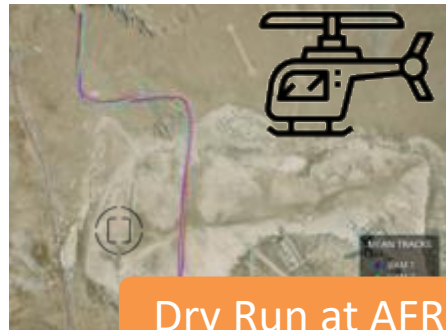


NC DT Dry Run as Risk Reduction for DT

The primary objectives of these flight tests are to demonstrate maneuvers for key flight characteristics of UAM vehicles, prove out initial concepts for UAM operational approaches and departures, and demonstrate each of the elements that are expected to form UAM mission profiles.

NC DT Dry Run Objectives

NC-1 Objectives



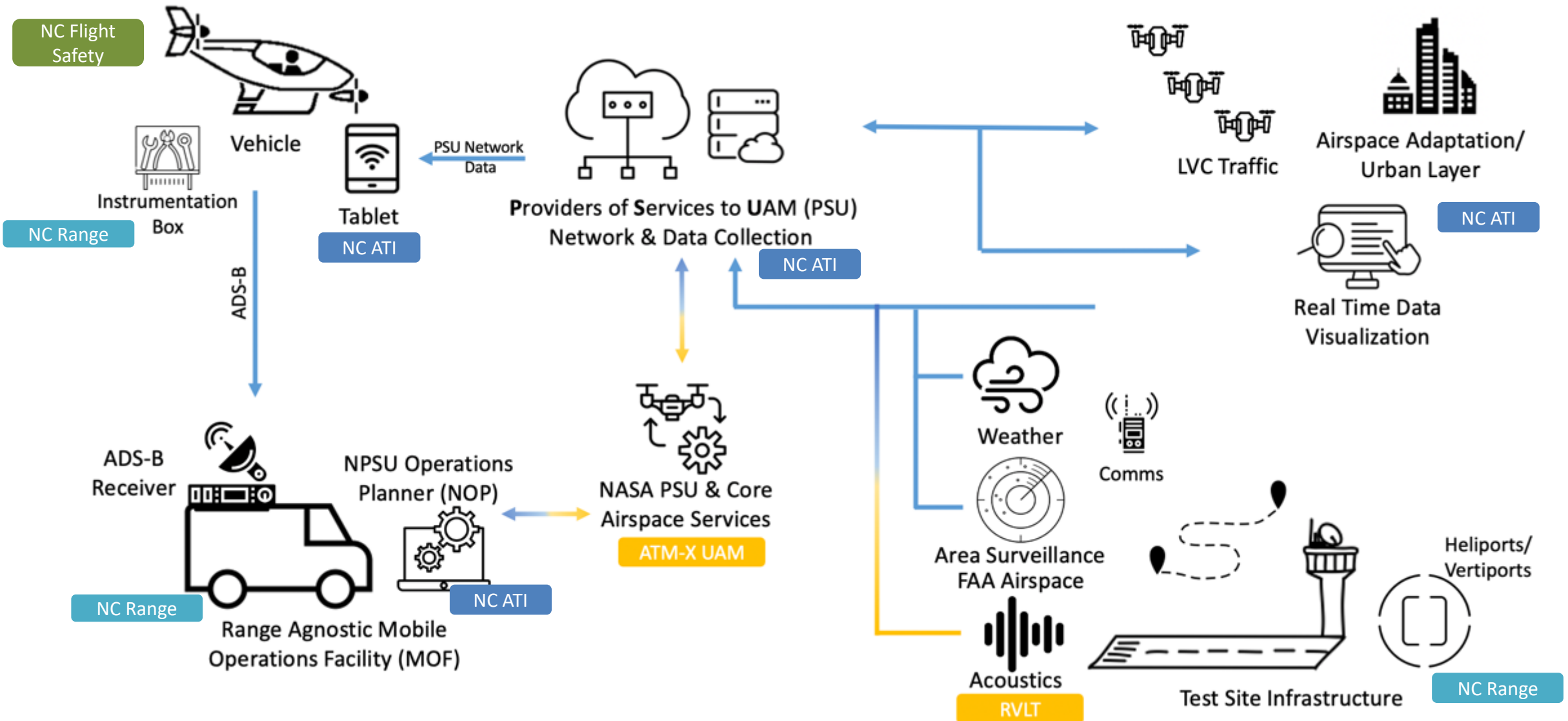
NC Developmental Test
with Joby

- ❑ Operational assessment and revision of NC scenarios using a helicopter as a stand in representative vehicle
- ❑ Assessment and development of Mobile Operations Facility (MOF) and its capabilities prior to deployment
- ❑ Assess operational processes for integrated operations with vehicle and airspace and data collection in the field



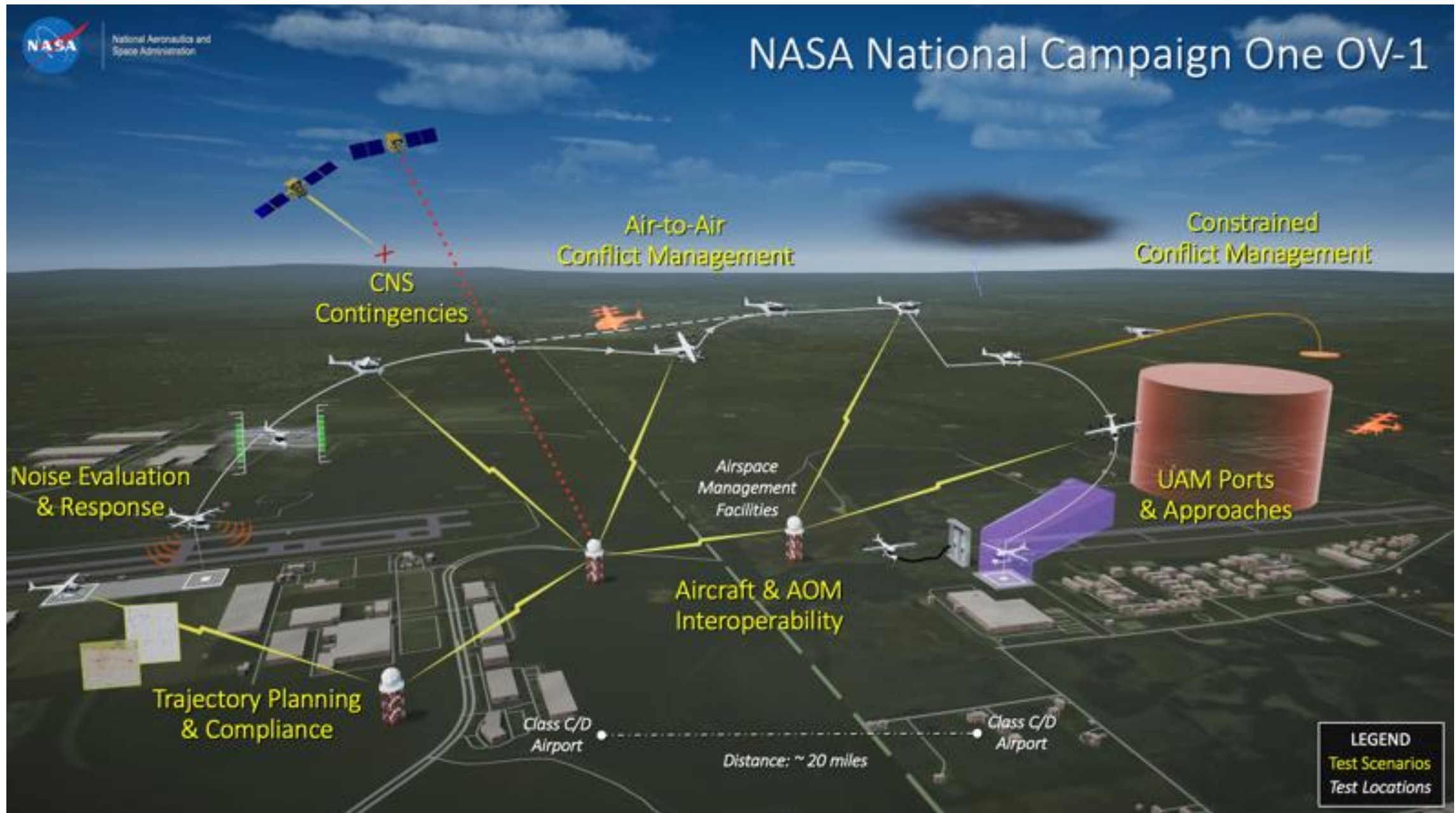
NC DT - Flight Interfaces Diagram

DT Flights with Joby mirrors Dry Run Build #3 but with flights and acoustic testing at Partner Test Sites



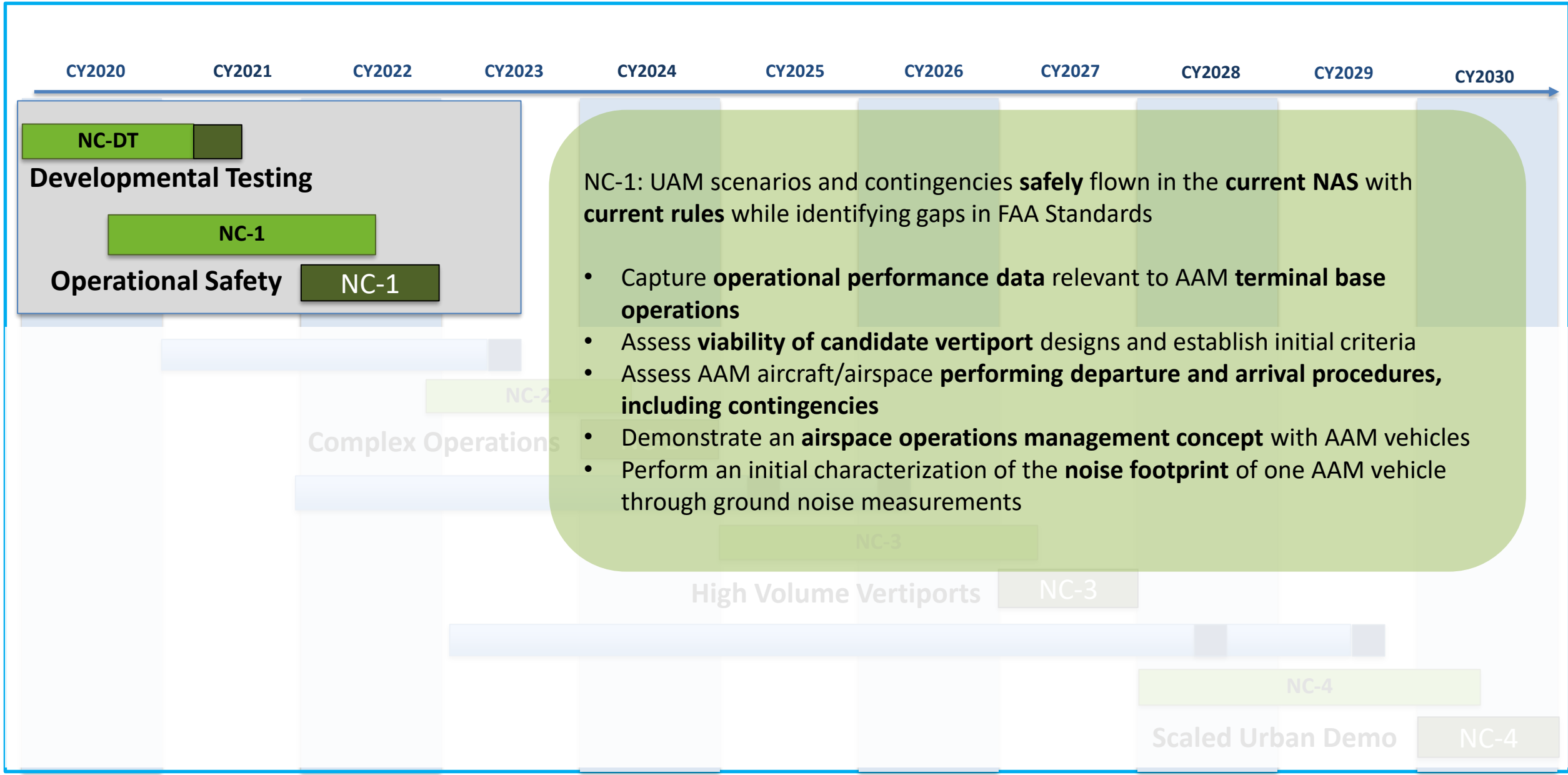


NC-1 Operational View



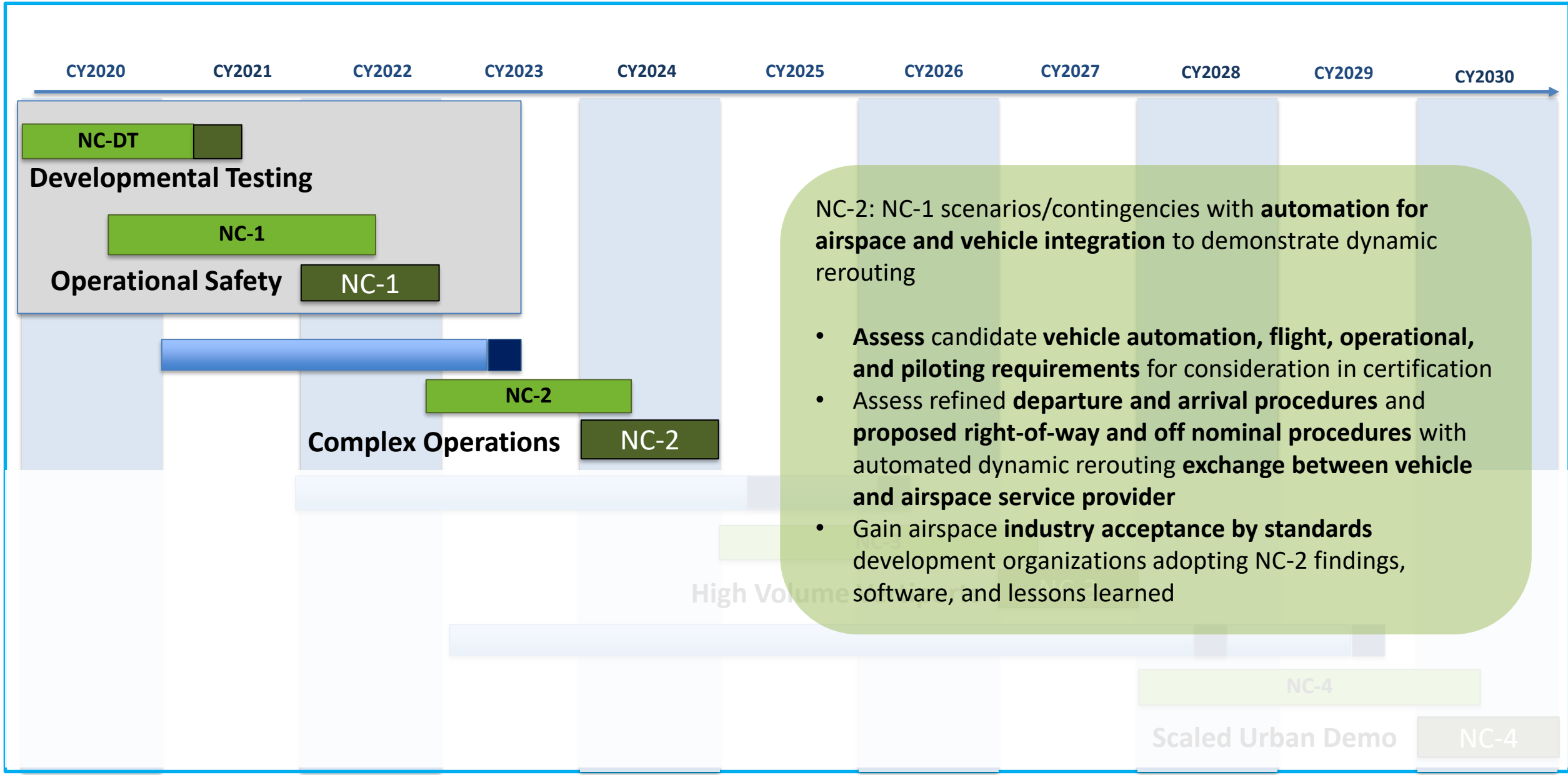


National Campaign Execution – NC-1





National Campaign Execution – NC-2



NC-2: NC-1 scenarios/contingencies with **automation for airspace and vehicle integration** to demonstrate dynamic rerouting

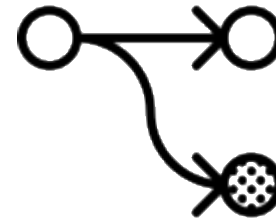
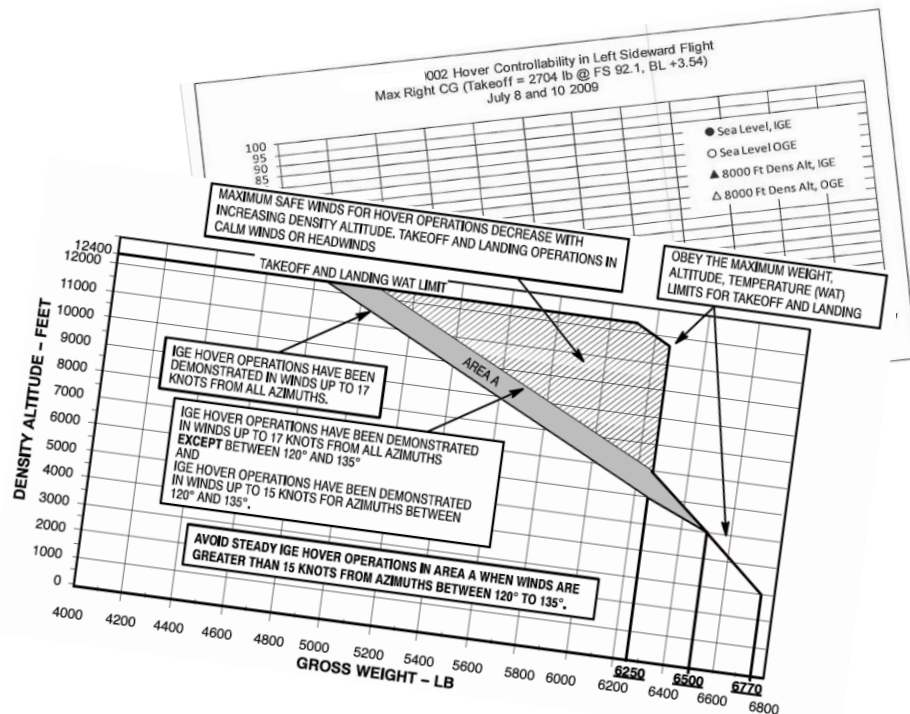
- **Assess candidate vehicle automation, flight, operational, and piloting requirements** for consideration in certification
- Assess refined **departure and arrival procedures** and **proposed right-of-way and off nominal procedures** with automated dynamic rerouting **exchange between vehicle and airspace service provider**
- Gain airspace **industry acceptance by standards** development organizations adopting NC-2 findings, software, and lessons learned



FAA Partnership with the NC is to “Anchor and Evolve Standards”



Collaboration with cross cutting lines of business in the FAA to develop NC scenarios, UAM task elements, and procedures ***anchored*** in today’s NAS



Leverage operational flight demonstrations and the data collected across the NC series to inform and ***evolve*** appropriate standards for UAM vehicles and policy to enable integration into a future NAS

NASA National Campaign flight demonstrations can provide the path to demonstrate a UAM vehicle in the Urban environment... ...well prior to certification

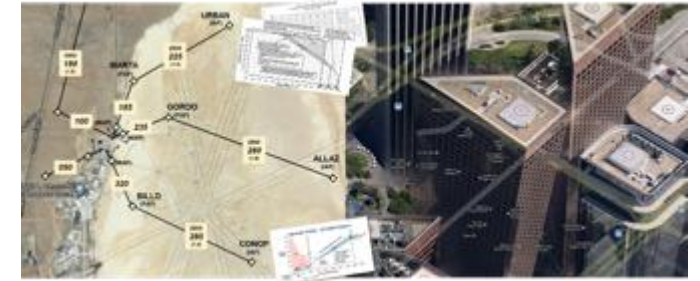


Key interest areas

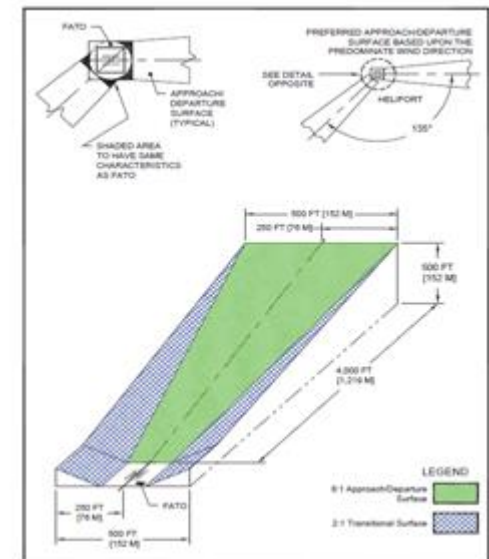
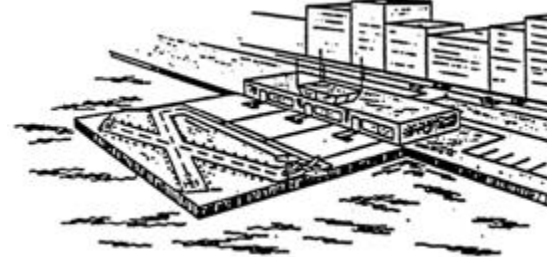
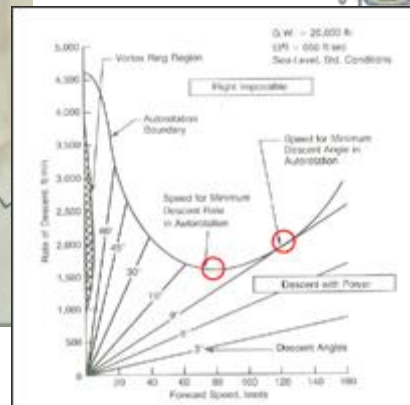
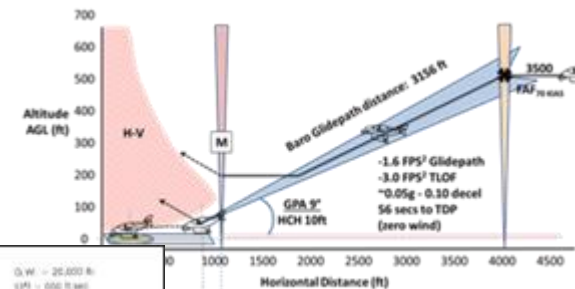
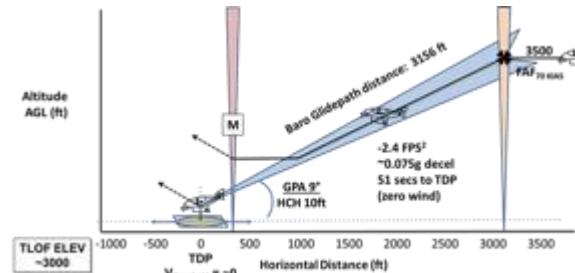
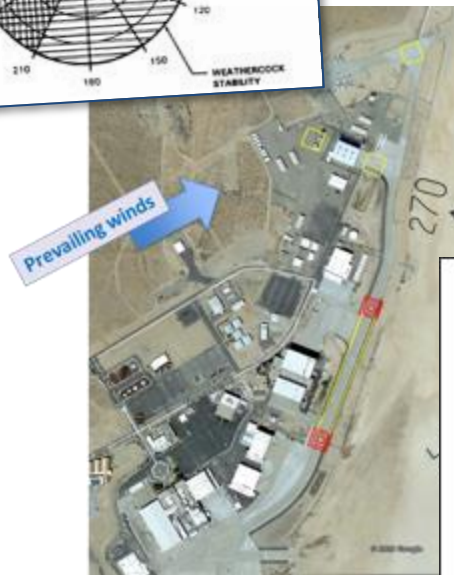
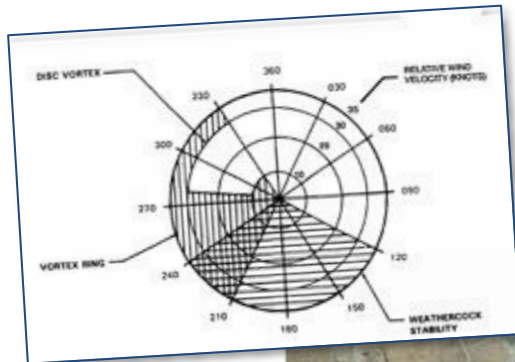


Low Speed Controllability/Performance in Urban Environment

Condensed UAM Approaches/Airspace

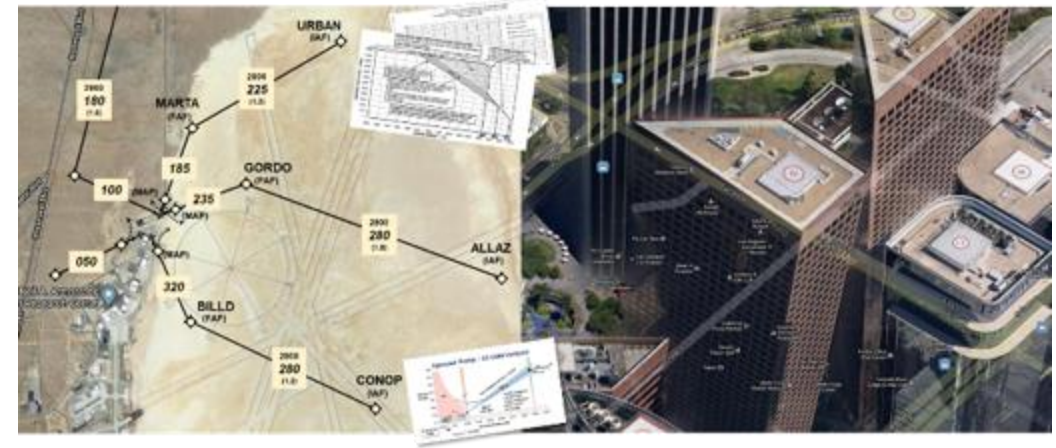


Required evolutions to
existing standards to
enable UAM



- **Select FAA “Subpart B” UAM Vehicle Characteristics baseline –**

- Performance
 - Hover Power Margin (IGE/OGE)
 - Level Flight
 - Climb/Descent/Glide
- Flight Characteristics
 - Flight Control System/Trim
 - All/Critical Azimuth Controllability
 - Maneuverability
 - Static & Dynamic Longitudinal Stability
 - Static & Dynamic Lateral/Directional Stability



- **UAM Task Elements –**

- | | |
|--|--|
| <ul style="list-style-type: none"> – Approach/Landing Characteristics (varied GPAs) – Deceleration IGE (Varied V_{AT}) – Ground Handling/Taxi Characteristics (Varied Winds) – Precision Hover (Varied Winds) – Lateral Reposition (Varied Winds) – Hover Turn and Hold (Varied Winds) – Acceleration IGE/OGE – Lift Mode transitions | <ul style="list-style-type: none"> – Maneuver Capability/Characteristics – Simulated Failure (TO/Land) – Enroute Climb – Path/Track Altitude Hold – Descent – Simulated GP/Localizer capture – Pirouette – Urban Landscape/Dynamic Interface – Go-around/Balked Landing |
|--|--|

- **Approach/Departure Routes initial look FIAPA (Flight Inspection Airborne Procedure Automation)**
- **Airspace System Function**
- **Integrated Scenarios Testing**

Characterize Vehicle Concepts and New Airspace Constructs

- Range Flight Vehicle Performance & Conformance
- Simulated Vehicle Performance & Qualities
- Simulated Airspace Performance & Qualities
- Vehicle Noise Evaluations
- Vertiport Design
- Weather & Wind Evaluations

Test Preliminary Operational Constructs

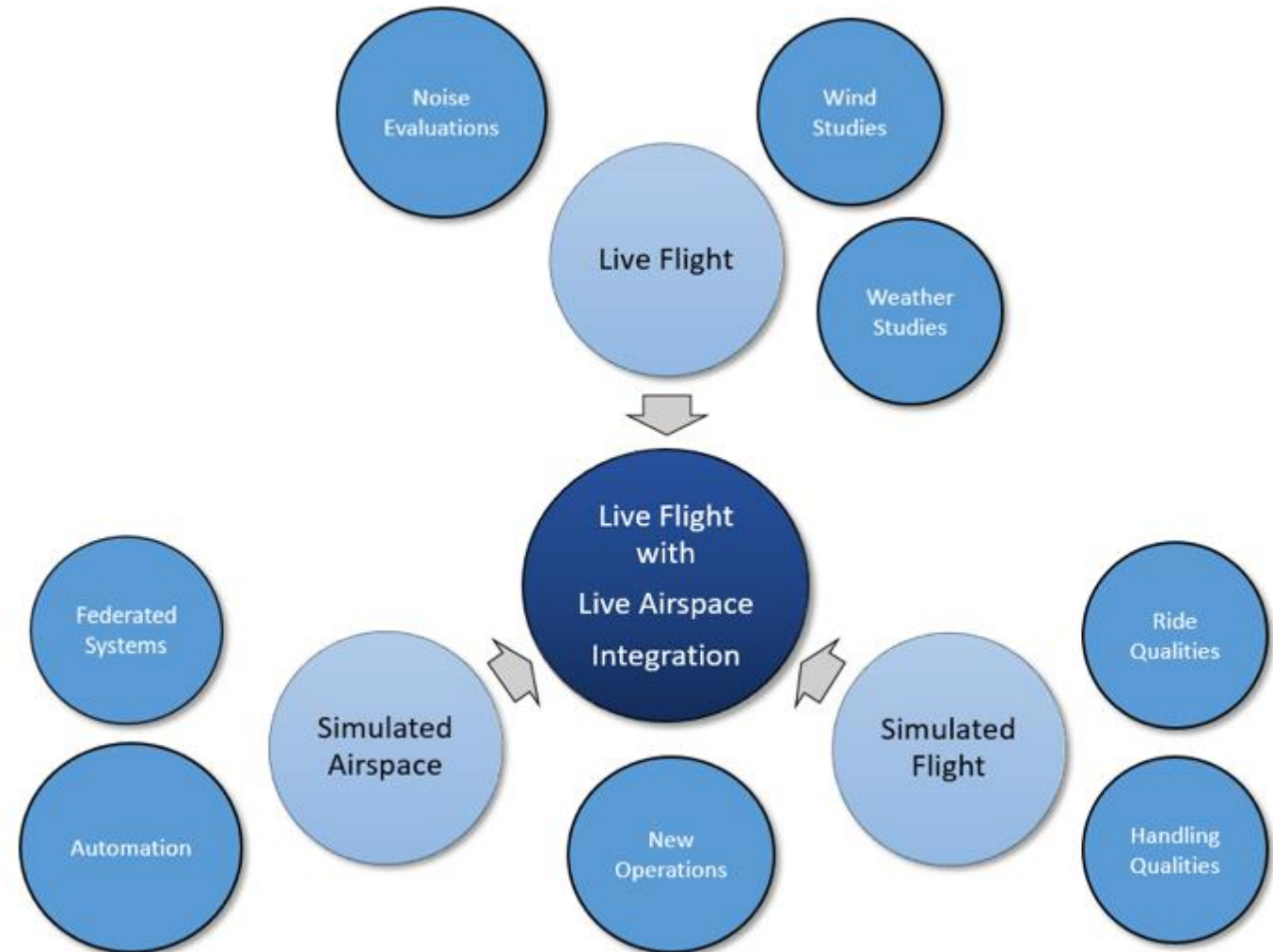
- New Vehicle Performance & Conformance
- New Airspace Parameters
- Critical Factors Affecting Operations

Optimize Operations

- Timing
- Sequencing
- Spacing

Evaluate Leading Risk Indicators, where possible

- Vehicle Performance & Conformance
- Vehicle Operations
- Airspace Operations
- Implement Mitigations, where possible





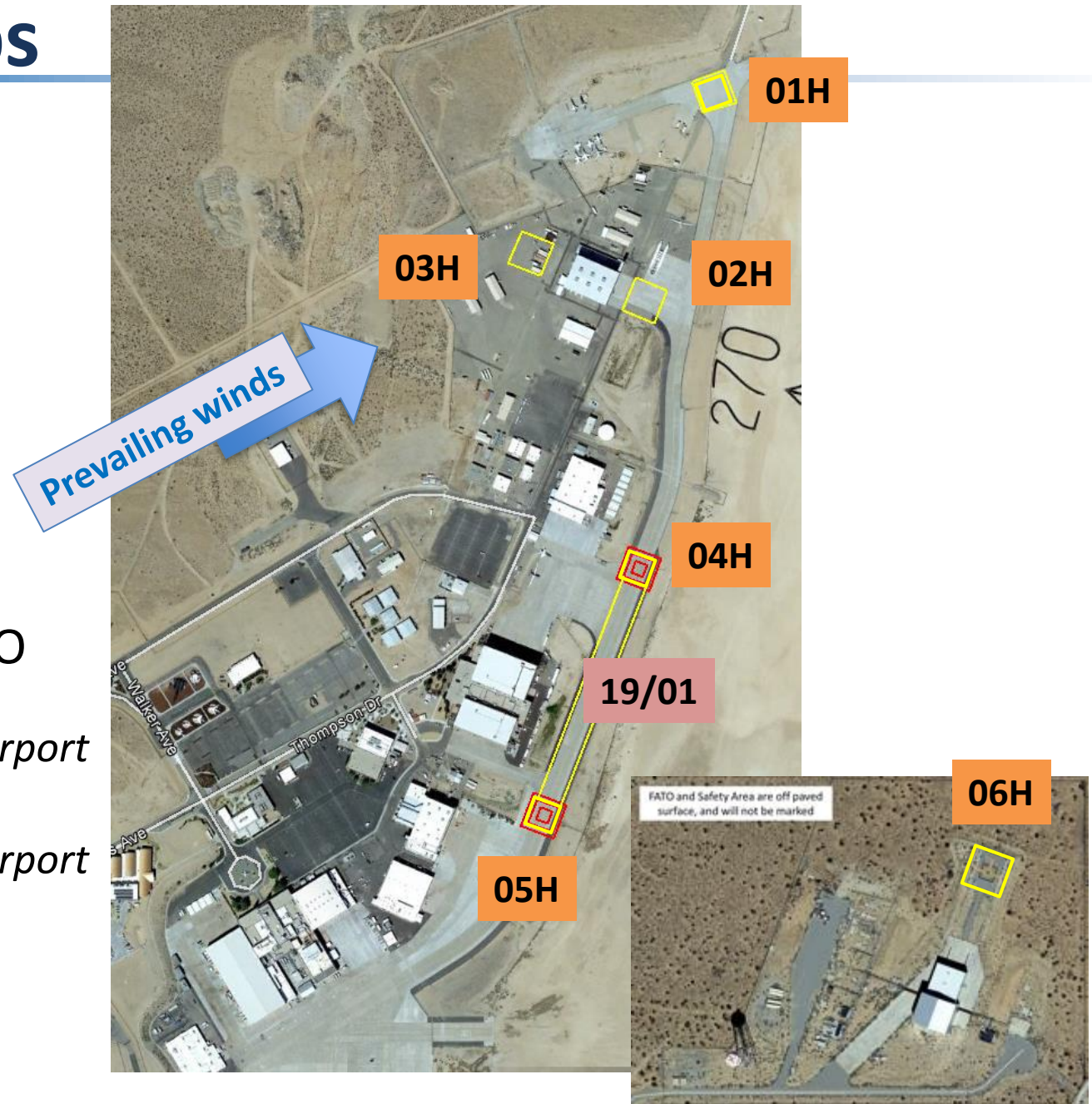
AAM NC Terminal Ops

6 AAM NC “UAM Heliports”

- 40x40ft TLOF
- Northern Heliports suitable for wind controllability studies
- All Heliport design/placement IAW AC 150/ 5390-2C Heliport Design

1 AAM NC “UAM Vertiport”

- 1090ft length x 120ft width TLOF/FATO
- **01H** + **02H** + **03H** = **XEDW** *Research Airport*
- **04H** + **05H** + **19/01** = **XVPT** *Research Airport*
- **06H** = **XX33** *Research Airport*





XEDW - 02H

RNAV - XEDW (02H)

Facility Search

Identifier

XEDW

AIRNAV Data

Airport

AIRPORT ID

XEDW

STATE

CA

COUNTRY

US

MVAR

E12

STATUS

Active

Runway

◀ 02H (A) ▶

General

LANDING LENGTH

31050 FT

TRUE BEARING

21.01°

PUB DATE

09/28/2020

FI RWY LENGTH

FI RWY HEIGHT

Helipad

LATITUDE

N34° 57' 24.3720"

LONGITUDE

W117° 52' 57.7200"

ELEVATION

2279.0 FT

ELLIPSOID ELEV.

2173.7 FT

MODEL / SOURCE

WGS84 / E

HORZ. DATUM

WGS84

VERT. DATUM

EGM_96

CALC ELLIP HT

2173.8 FT

IS DISPLACED

☐

NASA

XEDW - 02H - 033

LOCATION	34°57'32.88"N 117°52'54.07"W	FREQ/ALT	120.7
LDG. DIR.	315°	C/S	ARFC Tower
MIN/FREQUENCY	Concrete	CO ARFC	
ELEV(FT)	2277' MSL	LZ MARKING	Paint
SLOPE	0°	Total Slope	Active

A picture of the HLZ from an approach view.

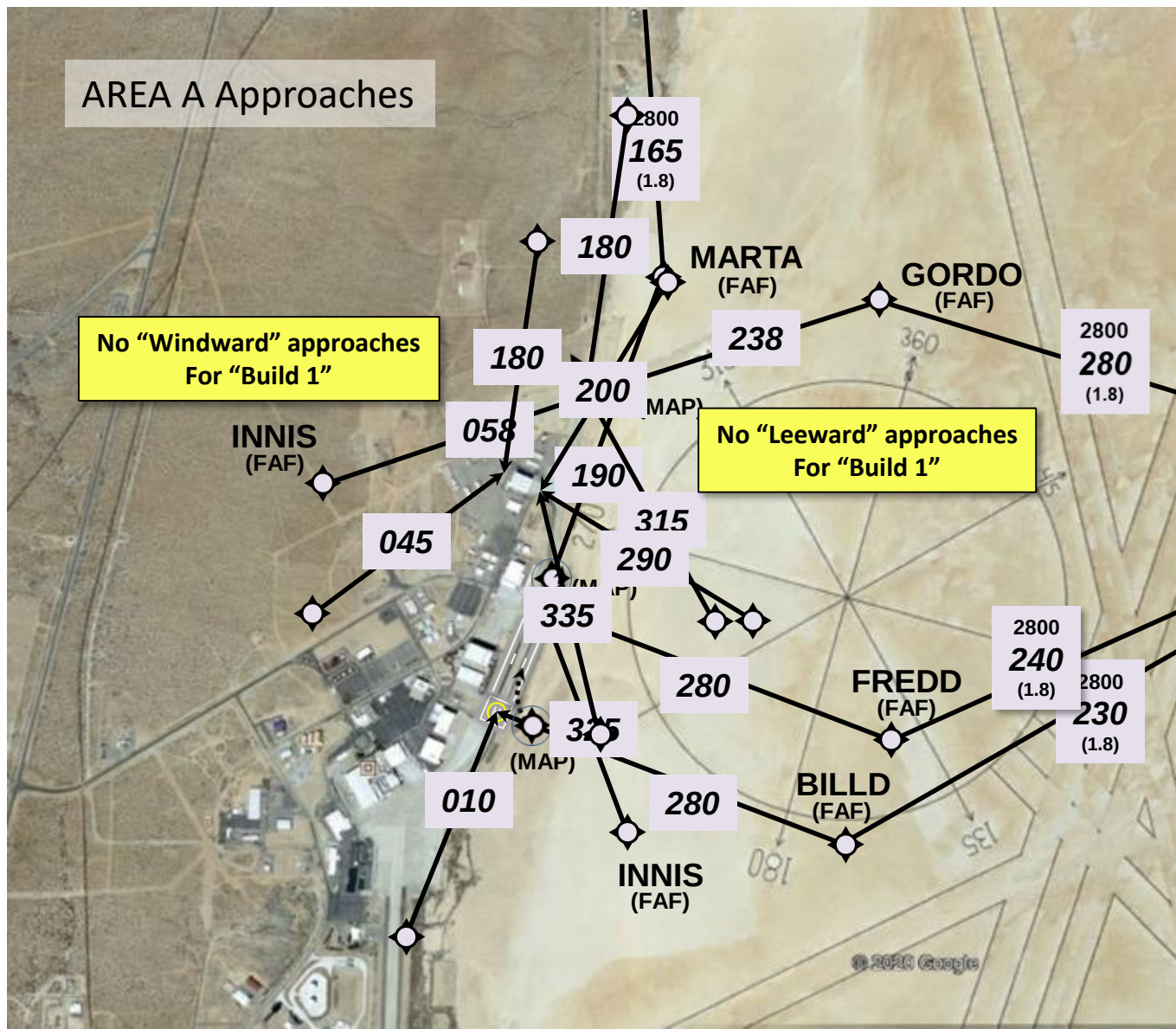
HAZARDS: Solid Rocket Boosters right side of LZ
REMARKS: Active Taxi-Way Approach End of LZ
INSTRUCTIONS: Constant Rate Decent Decol Approach to 10 ft AGL over center of LZ from FAF.
HLZ POC: Erin Waggoner Alt: N/A

UNCLASSIFIED // REL FOUO //

Info Updated Sep 1 2020 Plans Updated Sep 1 2020

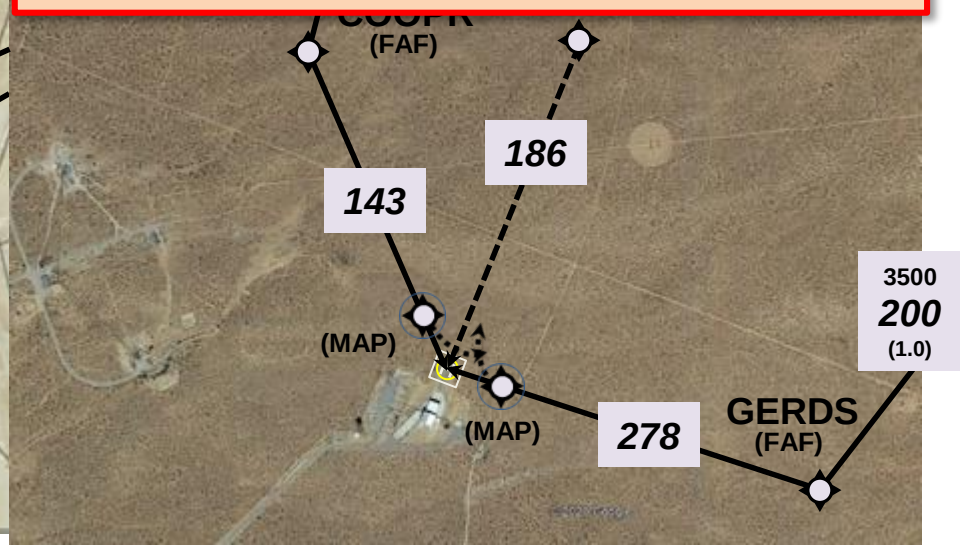


AAM NC Terminal Approaches



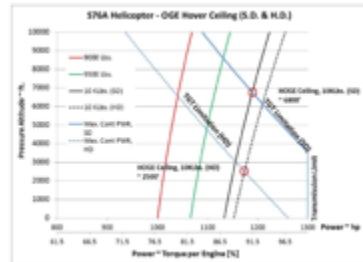
"Build 1" Limitations

- No Windward or Leeward Heliport Approaches
- No X-33 Approaches (overflight only)
- X-33 Area "Hard Deck" at 400ft AGL

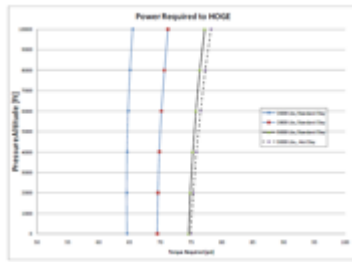




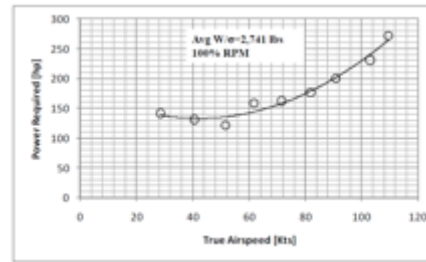
Performance requirements evolution



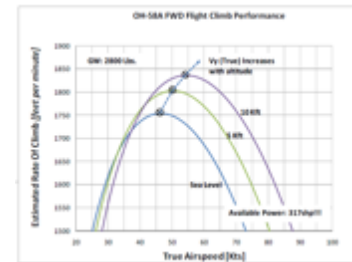
Hover Ceiling



IGE vs OGE



Level Flight

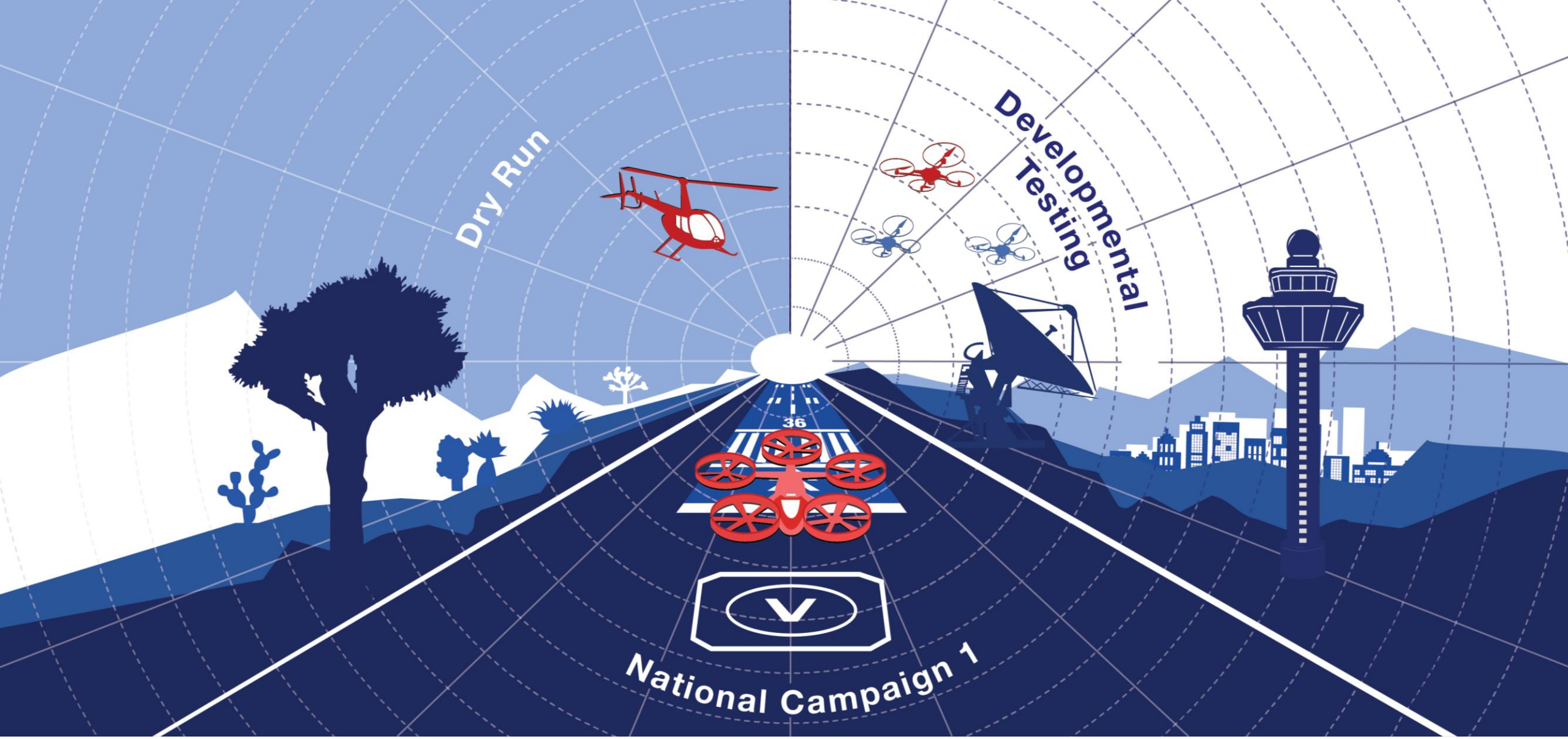


Climb Perf (V_Y)



Application of foundational tests/data to e/VTOL

- How do Power relationships in Helicopters compare to e/VTOL vehicles?
- Where do existing performance requirements for engines need to evolve for e/VTOL?
- How sensitive is e-power to atmospheric conditions?
- What is means (prior to takeoff) to determine propulsion system is capable of delivering the power required to achieve the published performance?
- How does “fuel” efficiency variation with airspeed/altitude/GW compare between helicopter and e/VTOL?
- What evolutions in Flight Test Techniques will be required for e/VTOL certification?
- ??
- ??

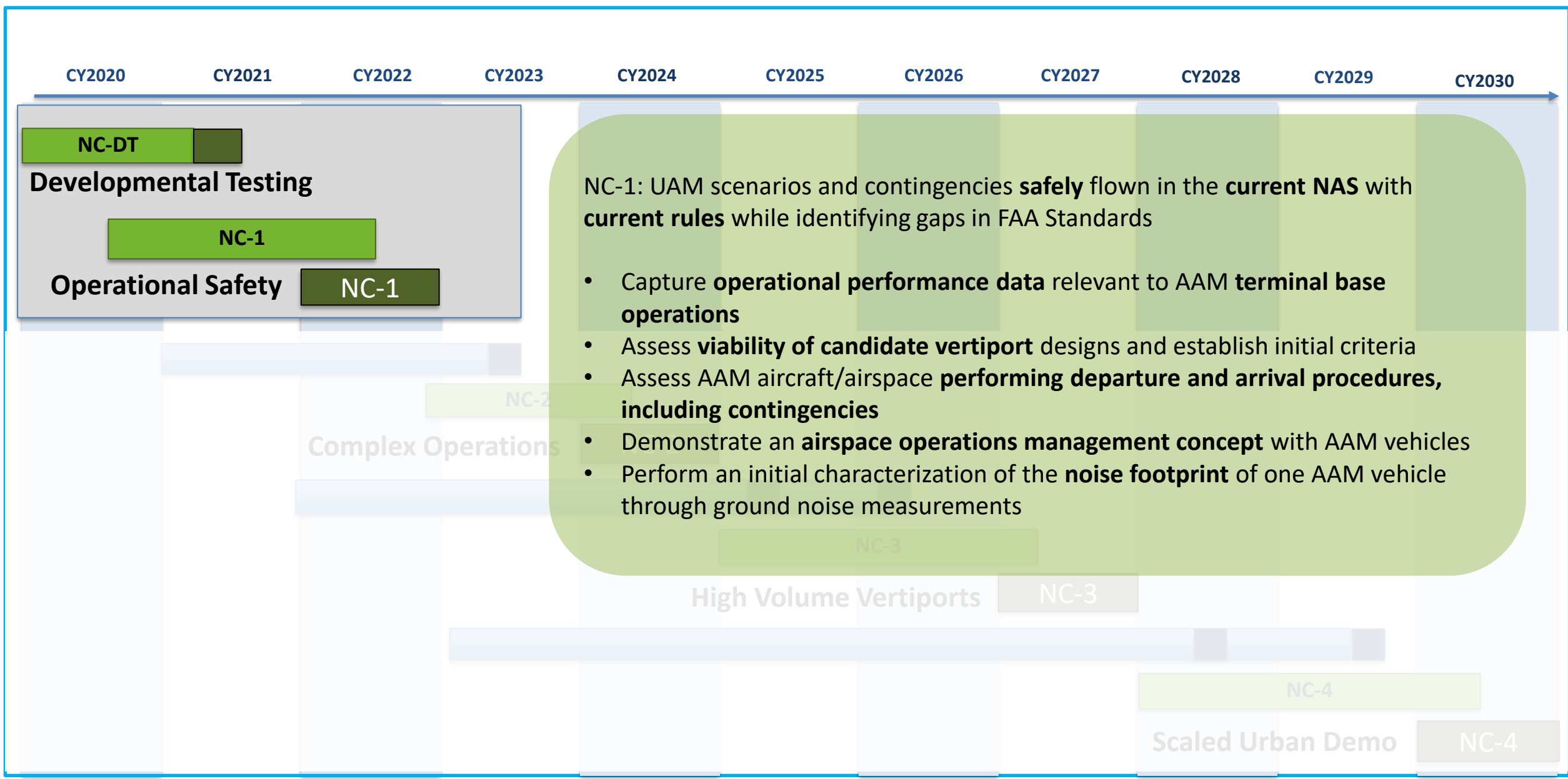


Breakout #1 NC-1 Flight Annex and NC-2 Information Exchange Annex
Starr Ginn National Campaign Lead



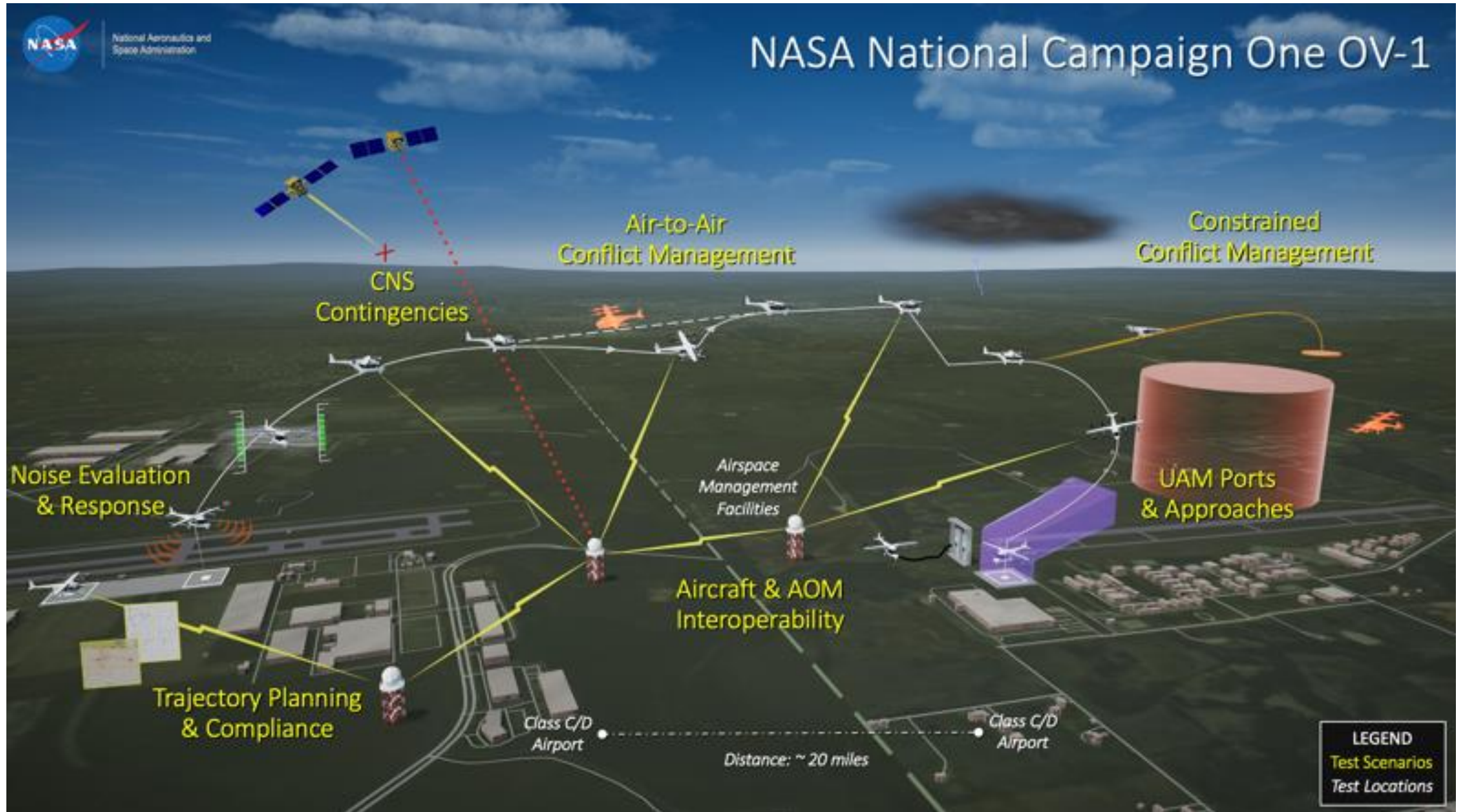


National Campaign Execution – NC-1





NC-1 Operational View





NASA Roles and Responsibilities

- Dedicate NASA management and systems engineering teams to develop and execute the NC-1 activity by coordinating with Partner vehicle and associated airspace service provider to execute NC-1 integrated scenarios.
- Provide a Flight Safety Review and sign-off for Partner vehicle/vehicles that will be flown manned/unmanned as part of the NC-1 activity using the process outlined in AFG-7900.3-001, AFOP-7900.3-022, and AFOP-7900.3-023.
- Integrate Partner-provided command and control or telemetry link and AAM airspace services within a flight test infrastructure to connect to the NASA communications system for communications and data recording.
- Provide Differential GPS (DGPS) payload package for the Partner to mount on their vehicle for onboard recording of aircraft high precision position during NC-1 flights. This system is not used for real-time data monitoring.
- Assist Partner and associated airspace services provider in developing Interconnection Security Agreement(s) in accordance with NIST 800-47.
- Collect Partner AAM vehicle data to include tracking and trajectory compliance, and vehicle robustness to contingencies of the Partner AAM vehicle, and other data such as pilot workload and vehicle emergency procedures during execution of the NC-1 scenarios.
- Collect acoustic measurements of the Partner AAM vehicle during execution of the NC-1 acoustics (and other) scenarios at the test range chosen by Partner for NC-1 flights..
- Publish a final report with the findings from NC-1 that covers the Partner activities and results.



Partner Roles and Responsibilities

- Provide documentation of intent to fly Partner vehicle(s) as part of the NC-1 activity, including: intended range or location for NC-1 flights, a schedule of anticipated NC-1 flights at the intended range or location, descriptions of the integrated scenarios that would be attempted, description of airspace services provider partner systems and capabilities, a list of additional partners and partner capabilities that will be leveraged in participating in NC-1, and any other information relevant to the Partner NC-1 flight activities.
- Provide vehicle design and analysis data to enable NASA to review range and ground safety for vehicles that will be flown unmanned, and additionally full airworthiness for vehicles that will be flown manned. Provide description of the proposed integrated vehicle and airspace operations that Partner intends to perform as part of the NC-1 flight activities to enable NASA to review intended flight operations and provide a flight clearance prior to NC-1 flights.
- Provide VHF/UHF radio to pilot in command for standard National Airspace System (NAS) operations.
- Provide C-Band Beacon for primary Range Safety Tracking.
- Provide vehicle with ADS-B Out for secondary source of Range Safety Tracking.
- Integrate NASA-provided DGPS payload package onboard Partner vehicle for recording of aircraft position during NC-1 flight operations, and de-integrate and return the package to NASA post flight activities.
- Comply with the NASA communications and any other interfaces that NASA defines for the NC-1 activity and provide real-time flight data during execution of NC-1 scenarios.
- Provide vehicle design and vehicle CAD models prior to flying NC-1 acoustics scenarios to help ensure that the acoustic measurement capabilities are best deployed for the particular Partner vehicle.
- Provide and fly a AAM vehicle or vehicles, along with associated AAM airspace services, to conduct safety and integration scenarios for the NC-1 activity in accordance with the NC-1 Scenarios document.
- Fly vehicle acoustics scenarios at the intended test range for NC-1, and measure and provide vehicle tracking and state data.
- Provide input to NASA covering Partner lesson learned, recommendations for future NC events, and details of flights conducted, and scenarios performed. This input will be used by NASA to write the report referenced in the NASA responsibilities section.

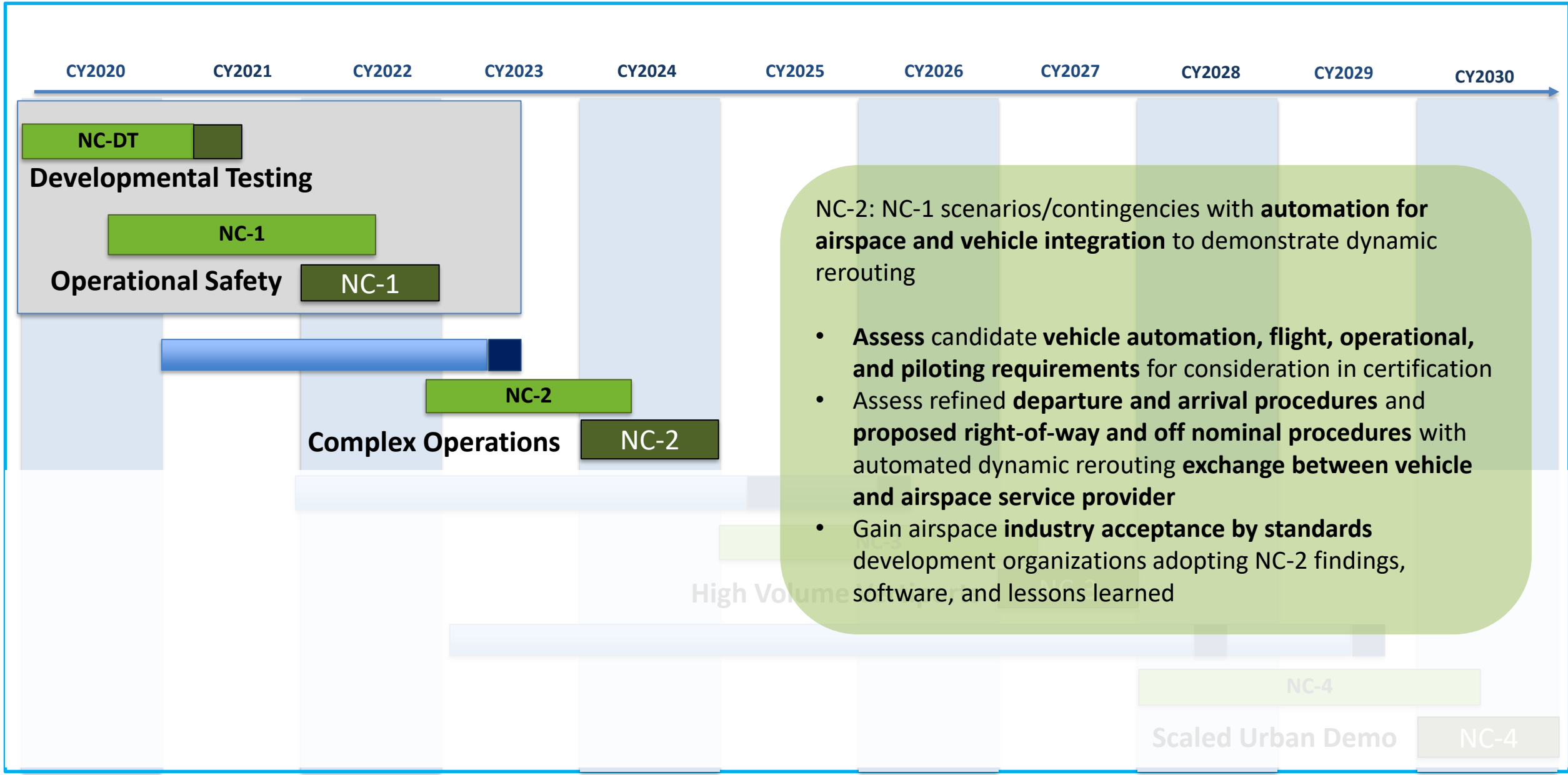


Schedule and Milestones

NASA to provide airworthiness, and range and ground safety process and requirements documents.	Within 1 month of signing Annex
NASA to provide communications interface documents and requirements to Partner.	Within 1 month of signing Annex
Partner and NASA to start vehicle airworthiness, and range and ground safety, review process.	Within 1 month of signing Annex
NASA to provide a liaison contact to help Partner through Airworthiness and Range Safety process, and in developing Interconnection Security Agreement.	Within 1 month of signing Annex
Partner to provide documentation of intent to participate in NC-1 flight activities, including a list of scenarios that will be flown, list of contributing partners (including airspace partner) and their capabilities, anticipated flight schedule, any other relevant information.	Within 1 month of signing Annex
Partner to provide vehicle envelope expansion flight data to demonstrate vehicle flight readiness.	3 months prior to flying in NC-1
Partner to provide vehicle design and CAD models to support noise measurements and noise data processing.	3 months prior to flying in NC-1
NASA to provide Differential GPS (DGPS) payload package for Partner to integration on their vehicle prior to flying in NC-1.	3 months prior to flying in NC-1
NASA and Partner to complete airworthiness, and range and ground safety, approvals for flight in NC-1.	1 month prior to flying in NC-1
Partner associated airspace service capabilities to demonstrate and document compliance with the NASA UAM Core Services API.	1 month prior to flying in NC-1
NASA to provide acoustics measurement capabilities at intended test range and collect acoustics measurements for Partner vehicle.	July 2022 – November 2022
Partner to fly integrated scenarios as part of NC-1 activities.	July 2022 – November 2022
NASA to deliver a final set of vehicle acoustics data to the Partner.	March 2023
Partner to provide input to NASA covering Partner lessons learned, recommendations for future NC events, and details of flights conducted and scenarios performed.	March 2023
NASA to provide final report with findings from NC-1 flight activities to demonstrate integrated vehicle/airspace scenarios.	March 2023

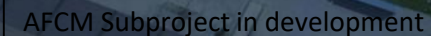


National Campaign Execution – NC-2



NC-2: NC-1 scenarios/contingencies with **automation for airspace and vehicle integration** to demonstrate dynamic rerouting

- **Assess candidate vehicle automation, flight, operational, and piloting requirements** for consideration in certification
- Assess refined **departure and arrival procedures** and **proposed right-of-way and off nominal procedures** with automated dynamic rerouting **exchange between vehicle and airspace service provider**
- Gain airspace **industry acceptance by standards** development organizations adopting NC-2 findings, software, and lessons learned





NASA Roles and Responsibilities

- Dedicate NASA management and systems engineering teams to develop plans for NC-2 by coordinating with Partner in information exchange in preparation for NC-2 flight and flight support operations.
- Provide an early flight readiness review board to evaluate Partner's capability maturity level in preparation for NC-2 flight operations, including at NASA's discretion, shadowing of Partner design, build and test reviews being conducted external to NASA to help accelerate progress towards NC-2.
- Provide an initial set of NC-2 external range requirements that are intended for Partner to follow when considering NC-2 flights at an external range/airport.
- Provide a set of NC scenarios that demonstrate key aspect of integrated vehicle, airspace and infrastructure needed for AAM operations.
- Conduct information exchange meetings with Partner to help introduce, explain and obtain feedback on NC-2 plans, procedures and goals, requirements for external ranges, and development of integrated AAM scenarios.



Partner Roles and Responsibilities

- Provide documentation for Partner plans to support flight operations of integrated scenarios as part of the NC-2 activity, including: details of the integrated scenarios that would be attempted, proposed range (NASA-sponsored or external range), a list of anticipated partners and partner capabilities that will be leveraged in participating in NC-2, any other information relevant to the Partner capability in NC-2. An initial set of NC scenarios is contained in the NC Scenarios document.
- Provide design and analysis data to initiate flight readiness review, and allow NASA to shadow any on-going Partner design, build, test activities that are being conducted external to NASA to help accelerate progress towards NC-2.
- Participate in information exchange meetings with NASA and provide feedback on NC-2 plans, procedures and goals, external range options and requirements, and integrated NC scenarios.



Schedule and Milestones

NASA to provide management and systems engineering teams to develop plans for NC-2	Within 1 month of signing Annex
NASA to provide an initial set of external range responsibilities and requirements.	Within 1 month of signing Annex
Partner and NASA to start design, build, test safety review process, and, at NASA's discretion, for NASA to shadow any vehicle design, build, test conducted by Partner outside of NASA.	Within 1 month of signing Annex
Partner to provide documentation of intent to support NC-2 flight operations, including a list of scenarios, any partners, range location, any other relevant information.	Within 1 month of signing Annex
Partner to participate in regular NASA-led information exchange meetings to provide feedback on NC-2 plans, processes and goals, range requirements, NC scenarios, etc.	Within 3 months of signing Annex